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ABSTRACT

This unit, one of a series designed to develop and foster an understanding of the marine environment, presents marine science activities for students in grades 9-12. The unit, focusing on sea plants/animals and their interactions with each other and the non-living environment, has sections dealing with: marine ecology; marine bacteriology; plankton; algae (producers); animals (consumers); sponges; jellyfish; shellfish; crustaceans; spiny-skinned animals; vertebrates; sharks; bony fish; salmon; marine animals; and current issues such as oil spills. Each section has a student text (including several readings from "Scientific American") with related activities. Each student text is preceded by a teacher background section containing hints on how to use the section, additional information, and items requiring advanced planning. Each activity is preceded by a teacher background section providing additional information about the activity, including teaching hints and answer key for activities. Important vocabulary words/terms are listed in the teacher background sections; they are underlined in the student text. Activities are designed to enhance reading and investigational skills; several activities provide practice in mathematics skills. Although all activities can be modified to suit individual needs or be used "as is," it is strongly recommended that they be performed along with the readings/discussions found in student text material. (JM)

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9-12

**MARINE
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PART II

MARINE BIOLOGY AND OCEANOGRAPHY

GRADES NINE TO TWELVE

PART II

MARINE SCIENCE PROJECT: For Sea
Educational Service District 114
P. O. Box 155, Federal Building
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MARINE BIOLOGY AND OCEANOGRAPHY

GRADES NINE TO TWELVE

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MARINE BIOLOGY AND OCEANOGRAPHY
GRADES NINE TO TWELVE

INTRODUCTION

The history of the United States is strongly tied to the seas. The future of the United States will also be strongly tied to the marine world. It is important that the leaders and the citizenry alike have a familiarity with the marine environment that will permit them to make wise choices in resolving the conflicts that are sure to arise over use of the ocean's resources. Marine Biology and Oceanography is designed to contribute to the knowledge necessary to make these sound decisions. In the development of Marine Biology and Oceanography, our goal has been to provide an opportunity for both the teacher and the student to become aware of the living and non-living factors that shape the life of the sea.

As the title implies, Marine Biology and Oceanography is presented in two units. The first unit, Oceanography, deals with the physical factors that influence life in the sea. Marine Biology treats the plants and animals of the sea and their interactions with each other and with the non-living environment. The divisions between the units are arbitrary and not strictly maintained. Each unit has been designed to be used in its entirety or just in part. It is recommended that the teacher incorporate his or her own ideas, experiences, and background to elaborate the subject material. It is important to develop the natural enthusiasm students have for learning about the sea. This is the time to add a bulletin board dealing with the marine world to your classroom. Displays of living and non-living marine creatures are also recommended. Use your imagination to create an exciting classroom atmosphere. National Geographic magazines are excellent sources of pictures. Incorporate some of the books listed in the "Bibliography of Selected Books about the

Marine Environment" section into your reading program. Investigate the audio-visual materials available from your supplier. Have students bring in their shell collections and other related items. These units have the potential for not only being worthwhile, they can be fun!

Each unit is divided into several sections. Each section has a student text and student activities. Each student text is preceded by a "Teacher Background" section which contains: hints on how to use the section, additional information, and items for which advanced planning is required. Important vocabulary terms are listed in the "Key Word" section of each "Teacher Background." They are also underlined in the text. The words are defined in the text, either directly or by context. All of the sections have activities accompanying the text. Most activities require few materials not ordinarily found in secondary science classrooms. It is strongly recommended that the activities be performed along with the reading and discussion of the text. Each activity is also preceded by a "Teacher Background" section. This section gives additional information about the activity including teaching hints and answer key. The activities are designed to enhance reading skills as well as investigational skills. Some activities provide practice in math skills. The activities can be modified to suit your particular needs, but will work "as is."

Skim the contents of the units to discover the organizational scheme. Please read the text and activities before you use them. The materials have all been prepared with ease of duplication in mind. Please feel free to duplicate any and all materials you need to effectively utilize this unit with your class.

Many of the laboratory experiences originated or have been utilized at the Marine Science Center. Teachers using these materials are given the opportunity to use the many resources available through the Marine Science Center staff. Our staff is available to you to give assistance in providing resource material and in setting up the unit of study. Please feel free to contact one of our

staff members by calling (206) 779-5549.

At the end of the text and activity section, you will find a "Send-in Page." We would like you to use it to let us know how much you liked or disliked the units. If you have some marine activity that you have tried successfully with your students, please let us know about it. Perhaps we can incorporate it in future revisions.

This unit is one of a series designed to develop and foster an understanding of the marine environment. Other units in the series include:

Marine Science Activities, Grade 2

Marine Science Career Awareness, Grade 4

Marine Science Activities - The Marine Environment, Grade 6

Marine Biology and Oceanography, Grades 7 - 9

Marine Biology and Oceanography, Grades 9 - 12, has been prepared with funds from ESEA Title IV-C Grant Number 35462 administered by Educational Service District 114 and the Superintendent of Public Instruction.

James A. Kolb
Project Developer
Author/Editor

A CONCEPTUAL SCHEME FOR MARINE AND COASTAL ENVIRONMENT STUDIES

BY MAIRA BEENS TYRRELL AND ROBERT W. STEGNER

1. AN ABUNDANCE OF WATER MAKES THE EARTH UNIQUE IN OUR SOLAR SYSTEM.

- 1.1 Water has a unique combination of chemical and physical properties.
 - 1.11 The chemical and physical behavior of water results in part from the geometry of the water molecule.
 - 1.12 Within the range of temperatures encountered on earth, water exists in three states: solid, liquid, and gas.
 - 1.13 Water exchanges large amounts of heat as it changes in state.
- 1.2 Water in the environment contains a variety of substances in suspension and in solution.
 - 1.21 Water is a very effective solvent.
 - 1.22 Dissolved and suspended substances affect the properties of water.
 - 1.23 Water in nature usually contains gases, organic compounds and mineral salts.
 - 1.24 Many elements dissolved in water are recycled through biological, geological, and chemical systems.

2. AQUATIC ENVIRONMENTS INTERACT WITH THE EARTH AND ITS ATMOSPHERE.

- 2.1 Most of the earth's water is in the oceans.
 - 2.11 Oceans formed early in the history of the earth.
 - 2.12 The earth's surface water is constantly recycled through the oceans.
- 2.2 The ocean waters are influenced by the earth's rotation, revolution, and position in the solar system.
 - 2.21 Ocean current patterns are affected by the absorption of solar energy.
 - 2.22 Ocean current patterns are affected by the earth's rotation.
 - 2.23 Tides result from gravitational forces of the earth, the moon, and the sun.
- 2.3 Energy is transferred wherever bodies of water meet the land or atmosphere.
 - 2.31 Atmospheric movements generate waves, surface currents, and coastal winds.
 - 2.32 Moving water shapes land forms.
 - 2.33 Subsurface topography is constantly changing.
 - 2.34 Land and sea floor movements generate waves.
 - 2.35 The aquatic environment helps to stabilize the earth's climate.

2.4 Materials carried from land masses influence the physical and chemical features of rivers, lakes and coastal zones.

2.41 Water, ice and wind carry minerals, nutrients, sediments and fresh water into rivers, lakes and coastal zones.

2.42 Fresh water from the land dilutes the coastal water.

5

3. AQUATIC ORGANISMS INTERACT IN COMPLEX ECOSYSTEMS.

3.1 Life probably originated in the marine environment.

3.11 Water facilitated the chemical evolution of organic compounds and coacervates.

3.12 Chemical evolution resulted in heterotrophic systems.

3.13 Autotrophs evolved from heterotrophs.

3.14 Aquatic environments have supported the evolution of a diversity of species.

3.2 Aquatic organisms are adapted to their environments in different ways.

3.21 Aquatic organisms are adapted developmentally, structurally, functionally, and behaviorally to their environments.

3.22 Organisms in aquatic communities interact in balance with their environment and with one another.

3.23 Populations of aquatic organisms are unevenly distributed.

3.3 Aquatic ecosystems depend on a constant flow of energy and the recycling of materials.

3.31 Energy for the maintenance of aquatic ecosystems comes from the sun.

3.32 Aquatic plants convert solar energy to food energy.

3.33 Aquatic organisms transfer energy and materials through food webs.

3.34 Aquatic bacteria reduce organic materials to simpler forms.

3.4 The stability of aquatic ecosystems tends to be directly proportional to the diversity of their populations and the complexity of relationships among them.

4. PEOPLE ARE PART OF AQUATIC ECOSYSTEMS.

4.11 Aquatic environments have affected the course of history and the development of human cultures.

4.11 Oceans, lakes, and rivers have served as routes for the dispersal of human populations and cultures and for commercial transport.

4.12 Proximity to aquatic environments and the availability of aquatic resources have influenced the cultures of many societies.

4.2 People's activities may alter the aquatic ecosystem.

4.21 People collect and culture aquatic resources.

4.22 Exploitation of aquatic environments can cause depletion of many marine and freshwater species and the degradation of habitats.

4.23 People are changing aquatic ecosystems by adding pollutants to land, to air and to water.

4.3 Existing technology is capable of maintaining the health and usefulness of aquatic ecosystems.

4.31 The maintenance of the health and usefulness of aquatic environments depends on value judgments and ethical considerations.

4.32 Regional and international agreements will be essential for the conservation of aquatic resources.

SUCCESSFUL FIELDTRIPPING

"Marine Biology and Oceanography" is designed as a self-contained curriculum equally appropriate for schools located on the edge of the sea and for schools located inland. As such, the activities included by and large do not require access to the water. If access is available, however, it can and should be utilized to broaden the experience and provide your students with further "hands on" opportunities to become familiar with the marine environment. The following guidelines are presented to help you lead a successful trip to the shoreline.



Proper Rain Gear

GUIDELINE FOR ROCKY INTERTIDAL FIELD TRIPS

The edge of the sea has fascinated man since earliest times. He used the margin to find a source of food and many of his gods were to be found in the sea. He looked to the margin of the sea as a defensive barrier to marauding enemies and as a passageway to trade with other units of society.

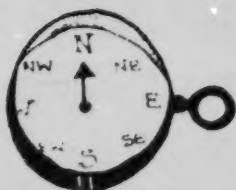
Why man is drawn to the sea has been a subject for philosophers, poets and physiologists. That he is drawn to the sea today is the concern of land developers, ecologists and the general citizenry.

Increasing human population, shortened work weeks, increased mobility and popularity of "environmental awareness", all contribute to greater numbers of people examining the magnificent beauty available to the human eye at low tide. The word "oceanography" has captured the imaginations of our citizens, including teachers and their students. The edge of the sea is most accessible to them and field trips are being taken by an ever increasing number of groups and individuals. In too many places the result of this increased utilization of the environment has resulted in the modification of that environment from a veritable jungle to that of a desert.

These guidelines are designed to offer some suggestions to those planning group visits to the shore. Our goals are educational usefulness, environmental protection, safety and esthetic enjoyment. Our concentration is on the rocky shore because of its great abundance and variety of life. Suggestions are in four sections as follows: preparation (Plotting the Course); at the site (All Hands Topside); back in the classroom (Swabbing the Deck); and references. They are in the form of questions the field trip organizer should consider.

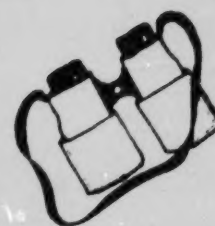
PLOTting THE COURSE

- A. - What are your objectives besides getting out of doors?
- B. - Have you personally visited the site?
 - Does the site minimize the inherent dangers?
 - By the way, have you checked the tide table for a + 1' tide or lower?
 - Have you established transportation and published itinerary?
 - Are you familiar with the state's intertidal rules and regulations?
- C. - Have you considered teaching aids such as films, slides, resource people, books, bulletin boards?
 - Have you established work crews (i.e. 5 - 8 with a captain for each)?
 - Does each crew understand its mission?
 - Where are you going to get your adult help? Parents? Bus driver? College students? High school students?
 - Has acceptable behavior been agreed upon?
 - Where is your food cache?
 - Would emergency telephone arrangements be useful?
- D. - Will everybody have pocket money for snacks, etc?
 - Do you know what salt water does to leather shoes?
 - Do you know what cold, wet conditions do to one's enthusiasm and attention span?
- E. - Why must you return rocks to their original position?
 - Do you know that when you crush a sea urchin you may be destroying 10 - 15 years of growing?
 - Have you considered that when you remove a six inch square segment of mussel bed you are destroying over 6,000 living creatures?
 - Does everyone understand that if you leave the organisms on the beach, the next group will be able to see them?
- F. - Do you have a first aid kit?
 - Will you have emergency transportation?
 - Do you know what barnacles do to naked ankles and sea urchins do to exposed toes?
 - Does each crew have a wave watcher and a tide watcher?
 - Smooth soles lead to departed souls. WATCH YOUR STEP!



G. Clothing, Supplies and Equipment for Your Trip

Clothing--Proper clothing is a very important consideration for the enjoyment and success of seashore activities. Most trips to the seashore need not be cancelled due to poor weather conditions provided that the participants are properly clothed. Weather conditions at the seashore are highly unpredictable. I have seen sun, wind, rain, and hail all in the same day. As a general rule IT IS BETTER TO OVER DRESS THAN TO UNDER DRESS.



It is essential that clothing be both comfortable and functional. Attention should be paid to the characteristics of different fabrics. The following suggestions are provided as a guide to proper clothing. You will need to add or delete items to fit the general climate of your area.

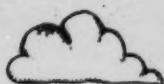
Rain Gear--One of the most important considerations when going to the seashore is how to keep dry. One way to choose the most appropriate gear is to examine what a fisherman wears. A fisherman wears good rubber boots with thick soles, woolen socks, a long nylon or rubberized rain coat with a hood or a fisherman's rain hat, and rubberized pants. A variety of synthetic substitutes can be worn, but it should be emphasized that such items as wind breakers, sweat shirts, and cotton jackets are not substitutes for water proof rain gear.



Emergency Rain Gear

Emergency Rain Gear--No matter how much you emphasize the importance of proper clothing there will always be a number of students and assistants who will show up poorly dressed. It is a good idea to bring along a dozen or so large plastic garbage bags. These bags are great because they can be fashioned into make-shift rain coats, hats, and boots. And get clear bags; they can be used as aquariums or as aids to writing during rainy weather.





Cold Weather Gear--Wools retain warmth more than any other material, even when wet. Fishermen often wear heavy woolen sweaters, woolen mittens, woolen hats that cover the ears, woolen pants, and long woolen or thermal underwear.

Hot Weather Gear--On hot, sunny days the reflection off the water can cause severe sunburns and even sun strokes. This is particularly true of children who are not used to the out-of-doors. On first trips each child should bring along a long sleeved, cotton shirt and a cotton hat that can be tucked into the back pocket. Cotton is an excellent material for any trip to the seashore because it can be worn under wool or under rain gear.

Cold Weather Clothing

Clothing Check List

Day Trip

Extended Trip



rain coat
rain hat
rubber boots
heavy woolen sweater
long sleeved cotton shirt
2 pair socks
2 pair pants

rain coat
rain hat
rubber boots
rubber pants or woolen pants
heavy woolen sweater
woolen mittens
3 pairs woolen socks
2 pairs cotton socks
2 pairs jeans
2 long sleeved cotton shirts
cotton hat
long woolen underwear



H. Supplies and Equipment

In addition to the supplies that each individual student is required to bring you will want to bring along some extra equipment and supplies for class activities. The equipment that you choose depends on the length and the specific purpose of your trips. As a general rule travel as light as possible.

I. Equipment for Collecting Plants and Animals:

wide mouthed gallon jars
plastic pails
shovel with short handle
kitchen sieves
small nets
putty knife
pocket knife



Hot Weather Clothing

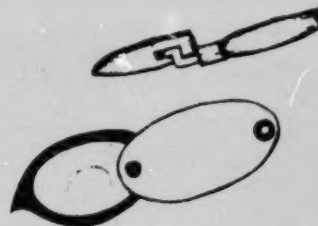
J. Equipment for Observing Plants and Animals

2 or 3 dozen clear plastic freezer bags
 rubber bands or bag twisters
 1 dozen $\frac{1}{2}$ gallon or gallon freezer bags
 wide mouthed jars
 clear plastic aquariums
 magnifying glasses
 microscopes (for extended trips)
 binoculars
 face masks



K. Equipment for Measuring Data

compasses
 thermometers
 stop watch
 metric stick or tape
 string
 baby bottle with measuring scale



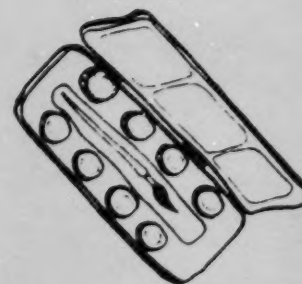
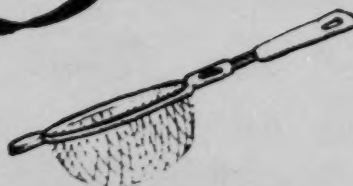
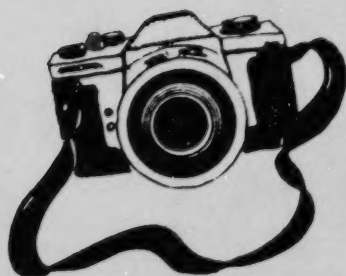
L. Equipment for Recording Data

field notebooks with pencil attached
 tape recorders
 cameras



M. Additional Equipment

local field guides
 extra spiral notebooks
 extra pencils
 newspaper
 toilet paper
 first aid kit
 large sketch pad
 water color sets
 pastels
 charcoal



ALL HANDS TOPSIDE

Are all present or accounted for? What are you going to do?
 Have you defined the physical boundaries for exploration?
 What is the direction and pattern of the waves?
 Are crews assembled with their equipment? Does each member
 understand his duties?

A. Have you scheduled a familiarization time for when you first
 hit the beach? What kinds of rocks are present? What birds
 are evident? Is there a lot of driftwood? How steep is
 the beach? What is the surf like?

B. What specific program will each crew carry out?

I. Observing?

Are there vertical bands of organisms? If so, how many
 are there?

How many different kinds of creatures are found under
 rocks?

Did you return rocks to original position?

How does a sea anemone feed? (Harvest one mussel for
 feeding experiments. How does a crab eat?

How does a limpet react to juice squeezed from a starfish?

Is distribution of organisms different on wave side of
 rock compared to lee?

II. Classifying?

How many kinds of algae can be found?

How do snail shell structures differ in sculpturing,
 hole size?

How many different ways do algae hold onto rocks?

How many different species of crabs can be found?

How do the various barnacles differ structurally?

How do color patterns and sculpturing differ among limpet
 shells?

How many different kinds of animals and plants can be found
 in one tide pool?

III. Measuring?

What is the temperature of a high tidepool? A low tidepool?
 The ocean? The air?

Among limpets of the higher rocks, what range of shell
 lengths are there?

How long does it take a sea anemone to swallow a bit of food?

How long does it take various starfish to turn over when
 placed on their topside?

How wide are the bands of organisms on rocks (if they are seen)?

If you use a squared wire coat hanger for area reference,
 what is the density of creatures at different levels of
 the tidal zone?

If you find barnacles feeding in a tidepool, how many times
 a minute do they rake their feathery feet through the
 water?

SWABBING THE DECK

- Will there be oral presentations, analyzing what each crew did?
- Will you share your experiences with other classes in the building?
- Will there be formal evaluation?
- Will you integrate the field experience with other experiences?
- Will there be a parent's night to show them what you did?
- Will local news media be invited?
- Have you or the students written thank you letters to those who helped you?
- Have you written thank you letters to the appropriate people if there was necessary first aid given?
- Do you have a file on what you will change the next time you go to the intertidal?

SAFETY - SPECIAL PRECAUTIONS

Any teacher should be aware of the potential dangers on the beach. Drift logs, steep and crumbly trails, treacherous waves, and incoming tides all must occupy a leader's attention.

1. Take only a group of manageable size to the beach. If your group is larger than 30 students, be sure to include an adequate number of properly briefed chaperones, to help keep an eye on energetic students. One adult for every 10 students is a good ratio.
2. Be sure the students are dressed properly for the trip. Long pants and tennis shoes (or rubber boots) are musts. Warm jackets are a good idea, as it is almost always chilly at the beach.
3. Be sure a first aid kit is available for the minor cuts and abrasions that are likely to occur.
4. Visit the site of the field trip before the trip date, to become familiar with the beach area the group will visit.
5. Study the tidetable; plan to arrive at the beach *an hour before low tide*. It is safer to be on the beach with an outgoing tide.
6. Check weather conditions before starting the trip; a stormy winter beach, with waves pounding, is not a place to take a group of students. Seas eight feet and above are considered rough; be especially careful to keep a good distance from the water line if you are on the beach under these conditions.
7. Playing and exploring around drift logs are sources of enjoyment, *but stay away from those near the water*. Logs are easily moved by only a small amount of water, and every year beachcombers are crushed by rolling logs.
8. Never build a fire in the drift logs. It can spread through the driftwood area.
9. Trails to the beach are often slippery and steep. On dangerous trails, station chaperones at intervals for an orderly descent to the beach.
10. While on the beach, always be on the alert for extra large "sneaker waves".

11. Don't let the incoming tide trap you or any of the group on a rock or ledge. Assign one of the chaperones to a "wave and tide" watch while on the beach.
12. Rock pinnacles are a challenge to most students, but they are steep and dangerous. Many are bird refuges, and it is against the law to disturb the birds.
13. Rip currents are a reality. Never allow students to wade or swim while on the field trip. Strong currents run out to sea and can carry inexperienced swimmers with them.
14. Assign the students to a buddy system while at the beach.

CONSERVATION

Rocky tidepool areas are limited in size; thousands of students visiting these areas during the spring low tide series can cause real problems of overuse. Stress conservation practices to the students before you leave the classroom.

1. Squelch the "save it and take it home" impulse. The replacement rate of some of the animals is not very rapid, and your collecting may deprive other students from ever seeing the more unusual species.
2. It is lawful to collect for a classroom aquarium or other selected educational purposes. Check the current angling regulations for information about tidepool animals. Or check with the Department of Fish and Wildlife for information about regulations and collecting permits.
3. When students pick up rocks that reveal hidden animals, be sure they return the rocks. Tubeworms, sponges, and other sessile animals live there for protection; they will die if left exposed.
4. If students pick up animals and examine them, they must return these to the spot where they found them. Some animals have specific feeding requirements, and they live at specific tidal heights. Moving them to another part of the beach can kill them just as surely as removing them *from* the beach.
5. Soft-soled rubber boots or tennis shoes are less damaging to the animals than heavy, hard-soled hiking boots. Selection of proper footgear can be another conservation measure.

BIOLOGICAL FACTORS:

Relationships - Marine Ecology

TEACHER BACKGROUND - The Nature of Oceanic Life - Three Level Guide

The sea abounds with life. The many forms of life interact in the myriad of ways which contribute to the stability of the marine ecosystem. Unlike terrestrial ecosystems in which the producers are macroscopic grasses, trees and shrubs, in the marine environment the dominant primary production of organic matter is carried out by microscopic plants. These minute organisms trap the sunlight and use it to provide the energy necessary to sustain all of the life of the sea.

"The Nature of Oceanic Life" provides an overview of life in the sea. It also serves as a preview for the ensuing activities. As such, the article is recommended reading for all of your students. Unfortunately, "The Nature of Oceanic Life" is difficult reading for many students. This article seems to typify a problem seen in teaching today: We can have articles that cover the material but are too difficult to read or we can have articles that can be read but do not cover the material. The three level guide presented here is one way to solve this seeming dilemma. Three level guides are based on what seems to be the general agreement that comprehension can take place at different levels of cognition. Harold L. Herber has called these levels 1) literal, 2) interpretive, and 3) applied. With the exception of the literal level, each level requires the product of the previous level or levels in order to function. The literal level of comprehension produces knowledge of what the author said. We all recognize that it is quite possible to identify and even repeat what an author has said without understanding what the author meant by his statements. The interpretive level of comprehension depends upon the reading performed at the literal level but carries the process a step further. At this level the reader derives meaning from what the author has said. The meaning is determined by the way the reader perceives the intratext relationships. The applied level of comprehension takes the product of the literal, (what the author has said) and the interpretive (what the author meant by what he said) and applies it in some practical or theoretical exercise.

At this level the reader is using his past experiences and knowledge to produce new ideas which extend beyond those immediately identifiable in the reading selection. It must be borne in mind that the level at which a person reads does not reflect upon her intelligence and that the level can change as the material changes. The most advanced engineers and scientists often read at the literal level if they cross into other disciplines. When we read materials from an area with which we have little familiarity, our level of comprehension goes down. Your students are no exception to this observation. The three level guide is a device used to improve a person's comprehension by focusing on important concepts at each of the three levels. The three level guide can be used with any material and is readily constructed. For aid in this regard please see:

Teaching Reading in the Content Area. 1970. Harold L. Herber. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 296 pages.

Duplicate the pages of the three level guide. One set is recommended per student. Spend a few minutes describing what is expected of the student. Suggest that the students read the statements in the three level guide before they read the article. In this way, the statements serve as a preview and your students will be looking for and expecting to see certain concepts. You may elect to have your students compare their answers by meeting in small groups. The process of resolving differences in opinion can be very instructive. Upon completion of the reading of the three level guide, discuss the guide by reference to the article. It is sometimes helpful to have your students note the page number and paragraph number where they found evidence supporting or refuting the statements in the guide. You can require your students to provide this information or you can offer extra credit for those that include it. Choose the technique that most appeals to you and best fits the needs and skills of your class.

KEY

A completed three level guide follows the "KEY WORDS" section.

KEY WORDS

carcass
concentration
dilute
interpretation
mesopelagic
nutrients
organic
paraphrased
pelagic
photosynthesis
productivity
phytoplankton
synthesized
upwelling

The Nature of Oceanic Life - Three Level Guide

Level I: Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those statements that are actually stated or paraphrased in the selection. Be ready to explain what is inaccurate about the statements that you do not check.

- X 1. The majority of the basic organic material that fuels and builds the life in the sea is synthesized within the lighted surface layers of open water by the many varieties of phytoplankton. p. 215, paragraph 4
- 2. The porpoise and the seal live in the mesopelagic zone, the dimly lighted midlayer of the sea. p. 217 drawing
- X 3. The ocean's deep bottom organisms feed on the depleted remnants of the constant "rain" of small debris and the occasional fall of a carcass. p. 215, paragraph 6
- X 4. Marine organisms have all evolved a similar mechanism for dealing with the fact that the phytoplankton they eat is in very dilute concentrations. p. 218, paragraph 4
- 5. "Pelagic trees" have not evolved because the necessary nutrients for "pelagic tree" growth are not on the ocean floor. p. 219, paragraph 2,3
- X 6. Coral reefs are amazing organic structures. Some coral reefs have a mass that approaches the total of all of man's building that now exists. p. 227, paragraph 3

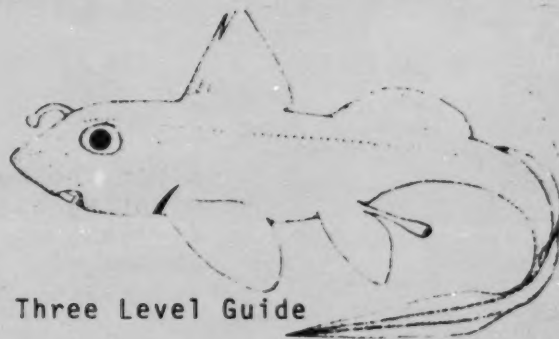
Level II: Directions: The following statements may or may not be true, based on what the author implies. Check those statements that you feel can be supported by the selection. Be ready to support your opinion.

- X 1. The fate of all phytoplankton cells is to sink to the ocean bottom.
- X 1. If all phytoplankton cells sank to the bottom, life in the ocean would cease.

- 3. Since the nutrients stored in the bodies of plankton end up below the zone with a level of light adequate for photosynthesis, the amount of life (#'s and weight) is constantly decreasing in the oceans.

THE NATURE OF OCEANIC LIFE

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TO COPYRIGHT RESTRICTIONS.



The Nature of Oceanic Life - Three Level Guide

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Level III: Directions: Read each statement below, relating the details and your interpretations drawn from the selection to ideas and experiences you've had in reference to this topic. Check the statements with which you agree.

- _____ 1. Upwellings of bottom waters such as those found off the coast of Peru may positively affect the productivity of the coastal waters.
- _____ 2. The ocean is a vast and rich storehouse of life waiting to be tapped by man.
- _____ 3. The most important thing for man to learn from the sea is how to immediately get more food.

TEACHER BACKGROUND - Name That Place!

"Name that Place" introduces your students to some of the terminology they will need for future discussions of the life of the sea. This section introduces several unfamiliar, yet similar, terms used to describe different areas of the marine realm and the creatures found therein. Activities designed to reinforce the learning of these terms are included. Incorporate the terminology into your speaking vocabulary to give your students an opportunity to become familiar with the terminology.

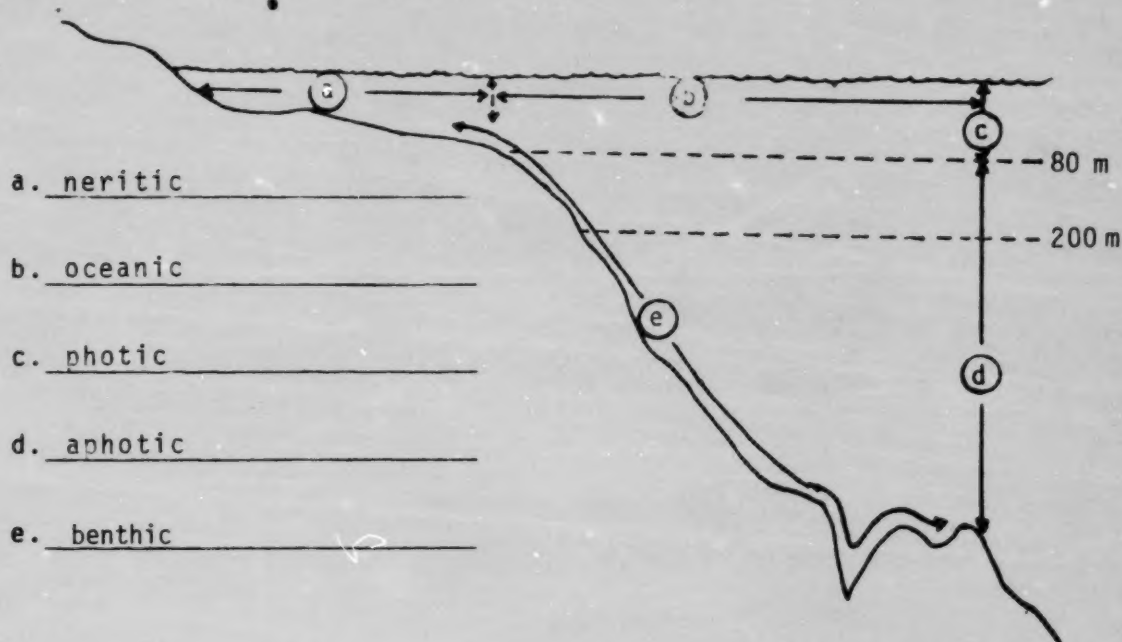
Duplicate the activity pages. One set is recommended per student. This activity may be performed individually or in small groups. Alternatively, the first section may be assigned for individual completion and the crossword puzzle may be done in small groups. Choose the plan that works best with your class. Set aside some time upon completion of the activity for a review of the answers to the questions and the crossword puzzle.

KEY

1. This question is designed to start the students thinking about food relationships in the vast ocean. The animals which live below 80 meters have several sources of food. They may swim up to the lighted zones and feed. They may eat dead organisms as they fall from the lighted zones into the darkness. They may eat animals that swim up into the lighted zones, etc. Encourage discussion but do not get sidetracked at this time. The concepts introduced here will be expanded upon in later activities.
2. The two photic zones found within the neritic zone are the euphotic zone and the disphotic zone. It is important to point out to your students that these terms are arbitrary and were created to help scientists converse about the ocean. The particular term used depends upon what the scientist is emphasizing in his discussion.

3. One would probably find more variety in shallow benthic areas because of the penetration of light. The light would allow plant growth which in turn would support a variety of animal types.

4.



5. Phytoplankton need to be in the euphotic zone to photosynthesize so that is where you would expect to find them.

6. An ocean desert is an area in the ocean with small numbers of plankton and hence small numbers of other organisms which depend upon plankton. The term seems to be a contradiction because "desert" usually refers to a lack of water - something we don't find in the ocean!

7. Nekton are found in all of the depth zones: neritic, oceanic and benthic.

8. One possible source of food for benthic organisms in the abyss is other benthic organisms! However, this source of food could only last for a limited time without additional input. The input comes from the continual rain of detritus (small dead organisms) and from the occasional large carcass that fall to the bottom of the sea.

9. The seemingly confusing terms were developed so that people could converse

about specific parts of the sea with a common set of terms. In spite of initial appearances, these terms aid conversation and understanding of the marine environment.

KEY WORDS

abyss

aphotic

benthic

benthos

disphotic

euphotic

nekton

neritic

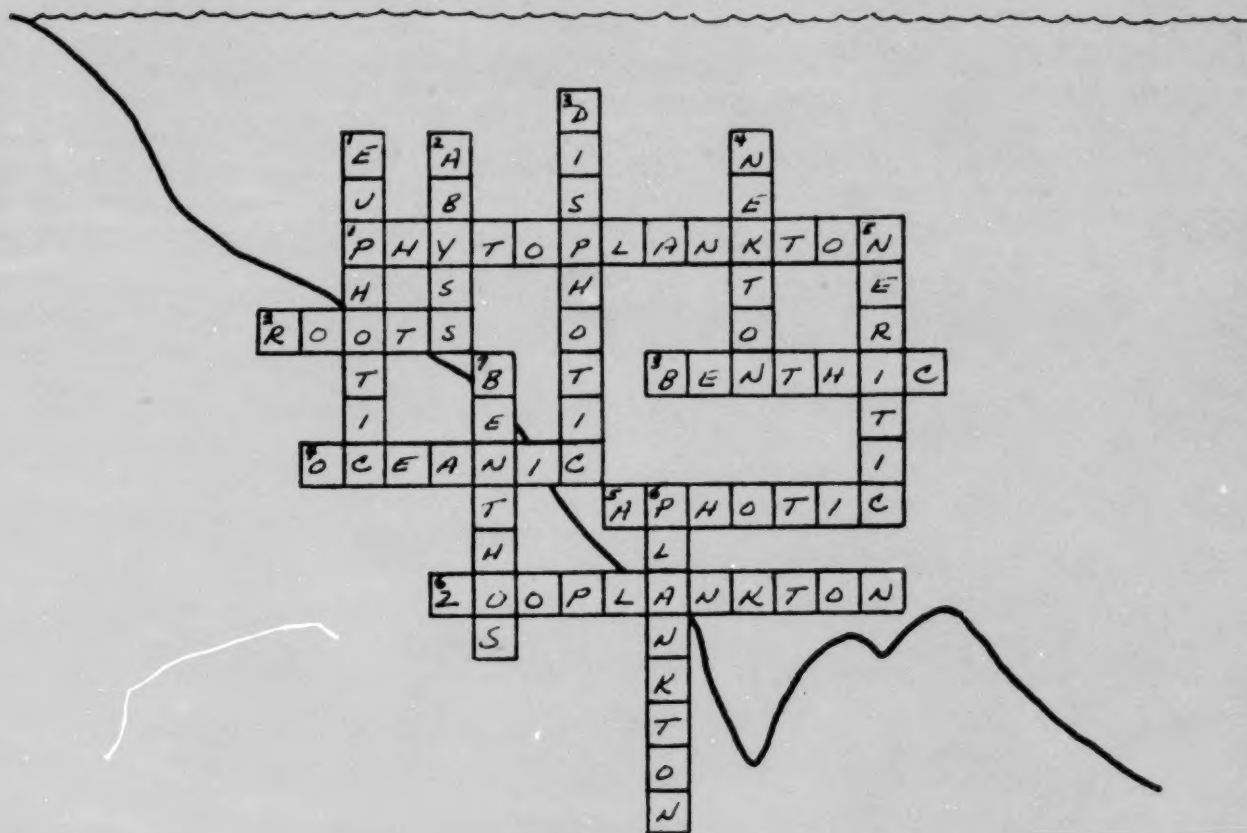
oceanic

phytoplankton

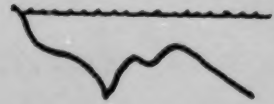
plankton

zooplankton

KEY - crossword



NAME THAT PLACE!



The ocean is such a vast kingdom that ocean scientists have had to divide it into smaller areas before they could begin to study the life of the seas. Two major types of divisions have been made: one based on light penetration and the other on depth. The divisions based on light penetration are called the photic (fo tik) zones (from the Greek word for light). Light is necessary for green plant growth. From the surface to a depth of about 80 meters the light penetration is great enough for photosynthesis. We call this area the Euphotic zone (meaning "true light"). Extending from the 80 meter boundary to about 200 meters, the Disphotic Zone (meaning "away from light") is an area of dim blue-green light. Finally, the area in which light is absent is called the Aphotic Zone (meaning "without light").

1. Below the 80 meter euphotic zone, almost no plant growth occurs. In spite of this, there are many animals which live below 80 meters. What is one possible way these animals find enough food to eat?

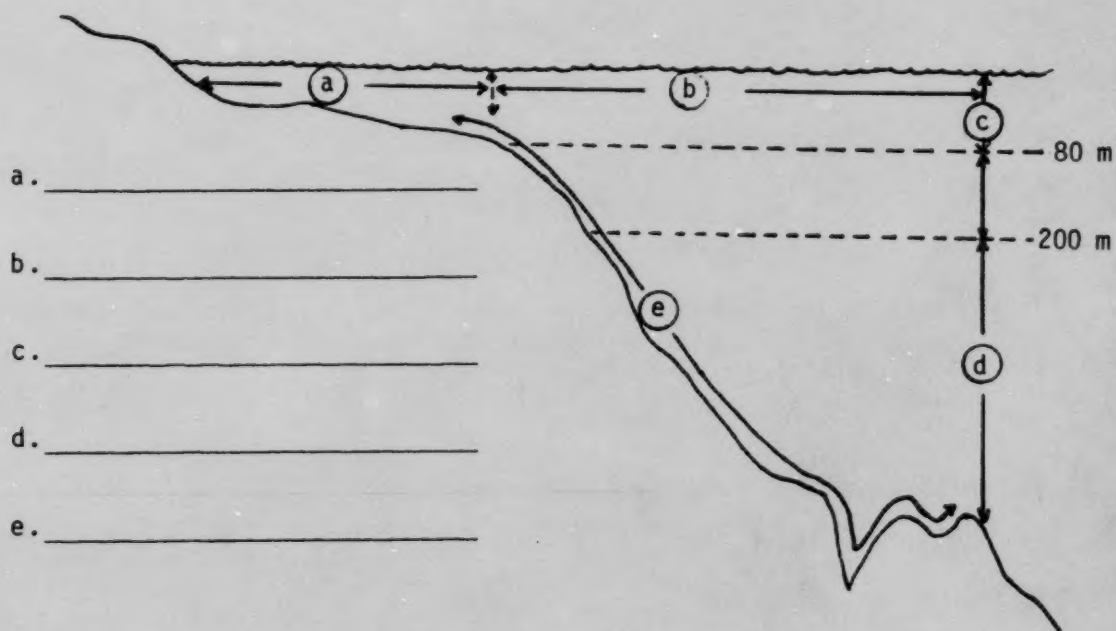
Oceanographers have also divided the ocean into two great areas based upon depth: the Neritic and the Oceanic. The neritic extends from the intertidal zone out to about the edge of the continental shelf or to a depth of about 200 meters.

2. Which two photic zones would you find in the neritic zone?

Beyond the neritic zone lies the oceanic. The oceanic province is very large and very deep. The abundance and variety of life in the oceanic zone is less than in the neritic. What lies beneath these ocean zones? Life that is on or near the bottom of the sea is found in the benthic division. The very depths of the ocean are the abyss.

3. Where might you expect to find more variety in living things, in a shallow benthic area or in an abyssal area? Explain your reasoning.

4. Use the drawing below. Each letter represents one of the ocean zones mentioned above. There is also a blank corresponding to each letter. Fill in the blank with the name of the zone indicated by that letter.



The plants and animals that are found within these division are also classified. They are usually placed into three divisions:

1. Plankton are plants and animals that drift at the mercy of the currents for locomotion. These free floating microscopic plants and animals are responsible for the colors of the sea. When you see clear blue water it indicates an ocean desert, or the lack of planktonic life. Plankton can be subdivided into two categories, the plant plankton or phytoplankton and the animal plankton or zooplankton.

The phytoplankton can be called the "grass of the sea". These small plants depend upon the sunlight to produce the food which becomes the basis for most of the life in the seas.

5. In which photic zone would you expect to find phytoplankton?

6. What is meant by the seemingly contradictory term "ocean desert"?

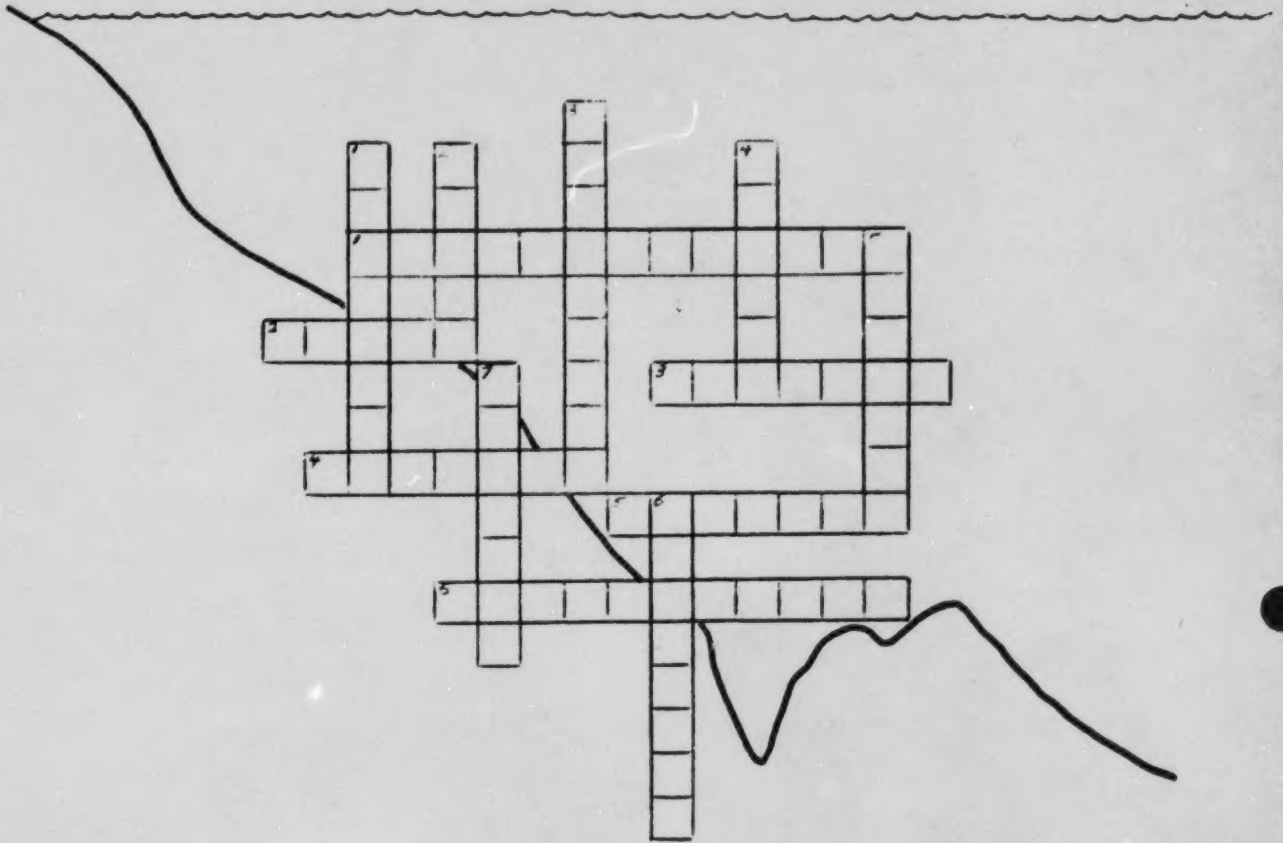
2. The nekton are the fish, whales, seals, sea turtles and some larger invertebrates such as the squid and shrimp. These organisms are capable of directed locomotion and can swim against the currents roaming over vast areas of ocean.

7. In which of the depth zones would you expect to find members of the nekton?

3. benthos or bottom dwellers represent the slow moving or sometimes sessile (non-moving) forms. In the coastal zones the chiton, barnacles or crabs, represent the Benthos. In the deeper abyss, specialized sea stars, urchins, snails, and bivalves are examples.

8. What is one possible source of food for benthic organisms in the abyss?

9. Benthic, abyss, photic, etc!, Why do you suppose scientists have developed so many terms to describe the sea and the things that live in it?

NAME THAT PLACE!

DOWN

1. This "true light" zone extends from the surface to a depth of about 80 meters.
2. The very depths of the benthic zone.
3. This zone is an area of dim blue-green light.
4. These organisms are capable of swimming against the currents to get where they want to go.
5. This zone extends from the intertidal zone out to about the edge of the continental shelf.
6. These free floating organisms are at the mercy of the currents for locomotion.
7. These organisms are the bottom dwellers.

Across

1. The "grass of the sea".
2. Phytoplankton don't have any of these to hold them in a single spot.
3. This division is the bottom of the sea.
4. This oceanic province contains the largest expanses and the deepest depths of the ocean.
5. This zone is perpetually dark.
6. Free floating animals that are at the mercy of the currents.

TEACHER BACKGROUND - Marine Ecology

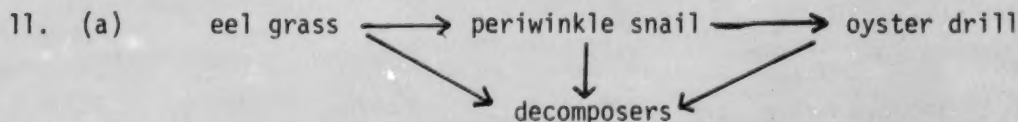
"Marine Ecology" provides an introduction to some of the basic concepts of ecology. For some students the material may be a review; for others, it will be entirely new. As with any introduction in the sciences, the material is heavy in new terminology and vocabulary. Many of the terms are composed of several Greek or Latin roots strung together. You can help your students to use basic word attack skills to read and define the new vocabulary. Activities to help reinforce the learning of the new terminology are included. Students often exhibit a low frustration level upon being assaulted by such an onslaught of unfamiliar vocabulary. You can reduce the frustration by being aware of the vocabulary and offering your students help and encouragement as they confront the many new terms.

Duplicate the text pages. One set is recommended per student. This activity should be performed individually and may be performed in class or as a homework assignment. As always, choose the plan that works best with your class. Upon completion of the activity, allow time for a review of the answers to the questions.

KEY

1. Ecology is the study of three general types of relationships we see in nature: (1) relationships among organisms of the same kind; (2) relationships among organisms of different kinds; and (3) relationships between organisms and the non-living environment.
2. An ecosystem is all of the living and non-living factors found in a given space.
3. The two major parts of an ecosystem are the non-living environment and the living environment or the biological community.
4. The 10 gallon jar is definitely non-living and yet is a part of the environment because it provides the boundaries to the living space that the members of a biological community require for their existence. The jar provides the living space.
5. The major difference between autotrophs and heterotrophs lies in the fact that autotrophs can produce their own food while heterotrophs must obtain their food by feeding on other organisms or on particulate organic matter.

6. The definition should build upon the previous definition of autotroph. You might have answers like "chemoautotrophs produce their own food from chemicals" (or "chemos" if the student can't make the transfer from chemo to chemical). Science teachers are in a unique position to help build vocabulary skills. Help your students to split words apart looking for familiar roots and encourage them to use context clues for defining words whenever the opportunity arises.
7. Chemoautotrophs generally use sulfur and nitrogen as the raw materials from which they manufacture food.
8. Heterotrophs are organisms that obtain their food by feeding on other organisms or on particulate organic matter.
9. Hopefully, the definition states that "omnivores eat all things", in other words they eat herbivores and carnivores and decomposers or a combination thereof.
10. In our mini-ecosystem the role of the periwinkle is that of herbivore. This might be a good time to introduce the term "first consumer". A first consumer is the consumer that eats the plant "first". First, and second order consumers and so on are terms frequently used in talking about food chains and food webs, concepts which will be introduced to your students shortly.



(b) An arrow from the decomposers to the eel grass would show that the nutrients or material released by the decomposers was used by the eel grass to produce new food.

(c) The answers to this question depend upon past experience. A wide variety of food chains are possible. Give credit for any that make sense.

An example:

giant kelp seaweed → sea urchin → sea otter

Food chains can have more than three links.

12. The ultimate effect of the eel grass blight will be death for all of the organisms in our system with the possible exception of the chemoautotrophs. The immediate effects will be different:

- (a) chemoautotrophs: The immediate effect will be small but an increase in raw materials may eventually increase their growth.
- (b) periwinkle snails: As the herbivore in the system, the snails will be the first to be without food as a result of the death of the eel grass.
- (c) oyster drill: The oyster drill will continue to exist without much change until the number of periwinkle snails begins to decrease due to their death by starvation.
- (d) decomposers: These will have an abundance of material for food and would be expected to increase in numbers then decrease as their food supply disappears.

In discussing the above results, emphasize the idea that the ecosystem operates as a whole unit and that damage to one ecosystem component will inevitably cause other changes in the ecosystem.

13. The organism that will feel the effect most rapidly will be the herbivores: the periwinkle snails.
14. The ultimate source of all energy that ecosystems use is the sun. (This fact was presented early in the discussion of marine ecosystems).
15. It is possible and, in fact guaranteed, that the nutrients that make up your body were once incorporated into the body of some other organism. It is possible that that organism was a cow in Nebraska or an elephant in Hannibal's service or, for that matter (sorry) Hannibal himself. You might discuss this uncommonly considered kind of immortality with your students. Our nutrients will be cycling into and through other creatures long after we're gone.
16. We should avoid making irreversible decisions for the obvious reason that we can't go back and change our actions if we find we have made the wrong choice. In dealing with living systems, its always wise to pre-serve as many options as possible.

KEY TO ECOGRAM

1. A U T O T R O P H S
2. D E C O M P O S E R S
3. E C O L O G Y
4. B I O L O G I C A L
5. N U T R I E N T S
6. E N V I R O N M E N T
7. E C O S Y S T E M
8. E N E R G Y
9. H E R B I V O R E S
10. H E T E R O T R O P H S
11. I R R E V E R S I B L E
12. P H O T O A U T O T R O P H S
13. C A R N I V O R E S

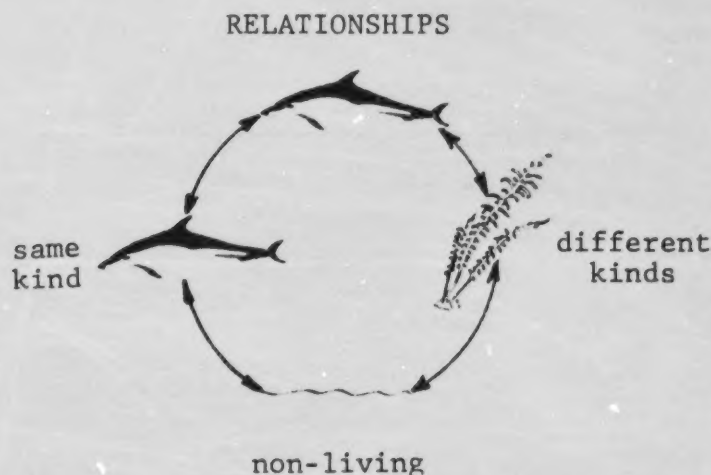
KEY WORDS

autotrophs
 biological community
 carnivores
 chemoautotrophs
 decomposers
 ecology
 ecosystem
 energy
 energy flow
 environment
 herbivores
 heterotrophs
 inorganic
 irreversible decisions
 living factors
 living space
 matter
 non-living factors
 nutrients
 nutrient movement
 omnivore

organic
particulate
photoautotrophs
relationships

MARINE ECOLOGY

Ecology.....hmmm, a popular word. What is ecology? Is ecology collecting paper and aluminum cans? Is it the balance of nature? Is it something to be "for" or "against"? Maybe we can tell by looking at the word itself. "Ecology:" comes from two Greek words "oikos" which means "house" and "logia" which means the "science or study of". Isn't that a big help? Ecology means the "study of house". Well, not quite but, maybe so.... Ecology is the study of the relationships that occur in our house, the earth. Ecology is the study of three general types of relationships that we see in nature: (1) relationships among organisms of the same kind; (2) relationships among organisms of different kinds; and (3) relationships between organisms and the nonliving environment..



Ecologists then study these three types of relationships as they occur in a particular volume of space called an ecosystem. An ecosystem is all of the living and nonliving factors in a

given space. We could look at the oceans as an ecosystem. Since we define the boundaries of the ecosystem, we would also call a particular bay or inlet an "ecosystem". The ecosystem concept lets us look at a particular area in detail. It is important to remember, however, that ecosystem boundaries are man-made. The real world is one single ecosystem in which all the nonliving and living factors affect each other to one degree or another.

1. What is "ecology"?
2. What is an ecosystem?

How could we study an ecosystem? Let's make one in a 10 gallon jar and see.



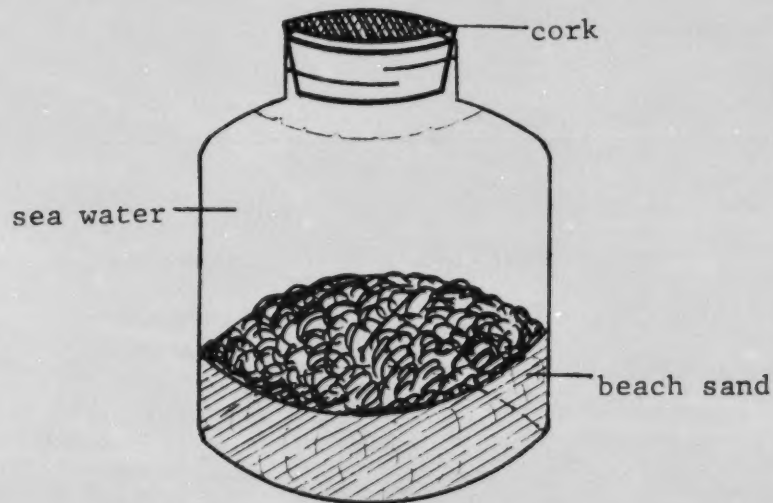
The Boundaries of Our
Ecosystem

What kinds of things would we need to make a sealed ecosystem that could exist for an extended period of time? Let's look at the components of the ecosystem. Think of the ecosystem as composed

of two major parts: The nonliving environment or surroundings and the living environment or the biological community. The nonliving environment provides the energy, nutrients, and living space that the members of the biological community require for their existence.

3. What are the two major parts of an ecosystem?
4. How could we call the 10 gallon jar part of the nonliving environment of our ecosystem? What does it provide?

Let's add 10 gallons of sea water and a couple of inches of beach sand to our jar to provide nutrients for the living organisms we'll need. But what about the energy? Lucky for us the jar is made of clear glass! The energy can shine right in...sunlight!!! Sunlight is the initial energy source for all of the ecosystems of the world.



Our ecosystem is now ready for us to add the biological community. What shall we add? One way of looking at the components of the biological community is to divide them into two major groups of organisms: The autotrophs and the heterotrophs.

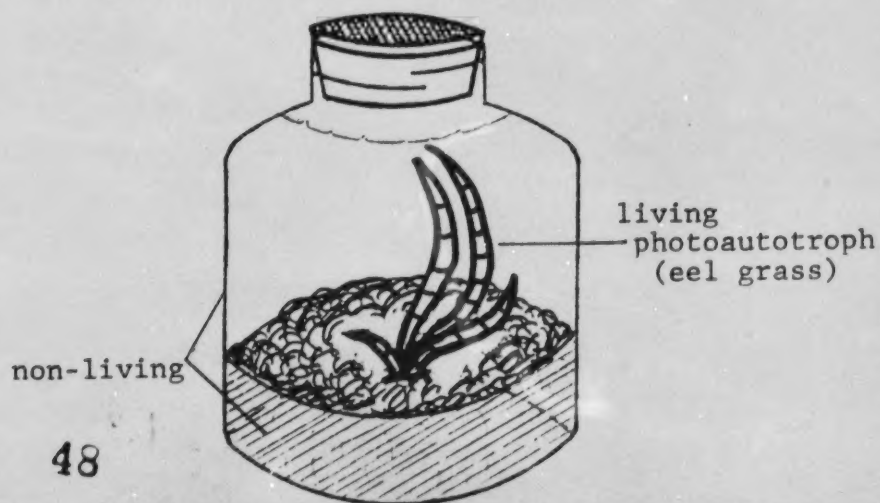
Autotrophs (auto=self + troph=food) are organisms capable of manufacturing their own "food" from simple inorganic molecules like carbon dioxide (CO_2) and water (H_2O). Most autotrophs are green plants. Heterotrophs (hetero=other + trophos=food) are organisms that cannot manufacture their own food. Heterotrophs obtain their food by feeding on other organisms or on particulate (small separate particles) organic matter such as a piece of seaweed that has washed up on the shore.

5. (a) What is a major difference between autotrophs and heterotrophs?

(b) Circle the autotrophs.

sea lettuce shark kelp periwinkle snail
seaweed oysters floating microscopic green plants

Okay...let's add our autotrophs. This might present a bit of a challenge since there are two large groups of autotrophs: photoautotrophs and chemoautotrophs. Wow! That's a mouthful. Photoautotrophs use the energy from the sun to manufacture food from simple inorganic molecules. (Photo=light + auto=self + troph+food). Incidentally, the process of using light energy to manufacture food from the simple inorganic molecules, carbon dioxide and water, is called photosynthesis (photo=light + synthesis=place together). What can we add for our photoautotroph? Let's add a couple of eel grass plants.



6. Use your knowledge of word parts to define "chemoautotroph".

Biologists often ignore chemoautotrophs. Chemoautotrophs manufacture the food they need with energy derived from special kinds of chemical reactions (chemo=with chemicals + auto=self + troph=food). (How close was your definition?) Chemoautotrophs are generally microscopic bacteria that use sulfur and nitrogen to make protein molecules. These protein molecules can find their way back into the living system as the bacteria are eaten by larger organisms. Since these bacteria can live in areas with little or no oxygen, they are sometimes very important in ocean areas with sandy or muddy bottoms. How can we add chemoautotrophs to our ecosystem? The bacteria are too small to see unaided let alone pick up. Fear not! The bacteria came in with our beach sand (hitchhikers) and will establish themselves just fine.

7. What do chemoautotrophs use as the raw materials from which they manufacture food?

So, now we have an ecosystem with a nonliving environment and a living environment. Are we finished? Well, we could be. Our system would maintain itself for awhile. The autotrophs could continue to grow until they ran out of raw materials. Can we add anything else that might make our mini-sea more interesting? Sure, we've neglected a whole group of organisms, the heterotrophs.

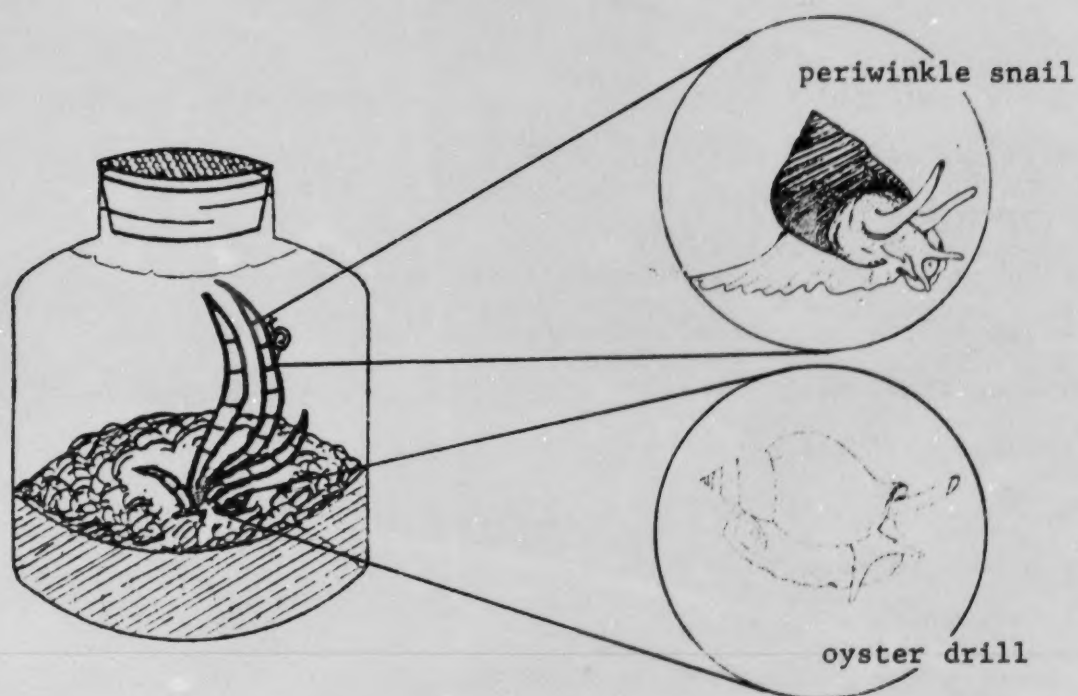
8. What are heterotrophs?

"Hetero" is a Greek prefix meaning "other or different".

Heterotrophs are organisms that obtain their food from other sources; they cannot make their own food. Since there are so many different organisms that fit into the heterotroph category, ecologists have divided heterotrophs into three groups: herbivores, carnivores, and decomposers. Each group has its own special way to obtain the energy and nutrients needed for maintenance, growth and reproduction. Herbivores are plant eaters. Carnivores eat meat in the form of plant eaters or other carnivores. Decomposers are organisms that use dead plant and animal materials as food. Decomposers play an important role in recycling nutrients. They break down organic substances, and use the energy and some of the nutrients stored in the "food". They return the remaining nutrients to the environment where they are available for use by other organism.

9. "Omni" is from a Latin word meaning "all". What do you suppose omnivores eat?

Can we add some heterotrophs to our ecosystem? Sure. Let's add some periwinkle snails which feed on the eel grass surface. To make things more interesting let's add an oyster drill that feeds on periwinkle snails. Now we have a complete system except for the decomposers. Many decomposers are bacteria. Aha! We've already added our decomposers with the sand. If we've picked the proper number of organisms, we could have a self-sustaining ecosystem that would maintain itself for long periods.



10. In our mini-ecosystem, what is the role of the periwinkle? Of the oyster drill?
11. The members of the biological community are listed below. Connect the members by drawing arrows that show who eats whom. Be sure your arrows point from the eaten to the eater.

eel grass

periwinkle snail

oyster drill

decomposers

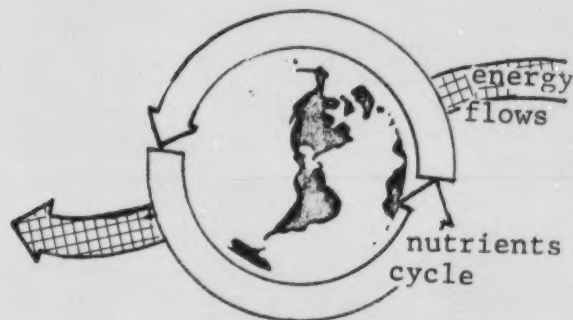
- (b) Why might you want to draw an arrow from the decomposers to the eel grass?
- (c) Your diagram above shows something called a "food chain". Use your knowledge of other marine plants and animals to create another food chain.

Now that you've built your ecosystem, let's take a look at the way in which it functions. It is important to realize that the ecosystem operates as a whole unit. What does this mean? Damage to one ecosystem component will inevitably cause other changes in the ecosystem. Since man is in the business of changing ecosystems, it is critical that we have as much knowledge about the anticipated change as possible. We can then be sure that the other ecosystem changes that follow the original change are minor and do not threaten the continued existence of the ecosystem as a stable unit. Nowhere is it more critical to understand the changes than in the marine ecosystem. Unfortunately, there is much we don't know. There is, however, much we can learn that is known.

12. Eel grass blight has been introduced into our system with the sand. What will happen to each of the other members of the living community if the blight kills all of the eel grass?
 - a. chemoautotrophs
 - b. periwinkle snails
 - c. oyster drill
 - d. decomposers
13. Which organism or group will feel the effect more rapidly?

Before we leave our ecosystem, we need to look at two ecological processes which lie at the heart of ecosystem structure and dynamics: 1) energy flow and 2) nutrient movement. Both energy and nutrients move from one member of the biological community to another as food. What is the difference between the two?

Energy flows while nutrients or matter cycles. What does this imply? Energy enters a system and passes through that system. Once energy passes through an ecosystem, it is lost forever; not so with nutrients. They are recycled from one system to another. Nutrients are almost never lost to the biological community as a whole.



Energy Flow is One Way
Nutrients are Recycled

14. What is the ultimate source of all the energy that ecosystems use?
15. Since nutrients cycle from one ecosystem to another, is it possible that some of the nutrients that make up your body were in a cow in the state of Nebraska last month? Could some of the nutrients have been with Hannibal when he crossed the Alps with his elephants?

Real world ecosystems are much more complex than the one we just built. The principals are the same but as you add more and more components the number of possible interactions increases dramatically. It is almost impossible to know all the things that will happen when one changes an ecosystem. The more we know the less the chance of making irreversible changes. In all of our decision making, we should strive to avoid making irreversible decisions.

16. Why should we avoid making irreversible decisions?

ECOGRAM

Use the clues given below to find the words to fill the thirteen lines. The correct answer will have the same number of letters as there are blanks in the ecogram. When you have filled in all of the lines correctly, an important ecological term will appear as if by magic!

1.	_____		_____
	2.		_____
	3.		_____
4.	_____		_____
	5.		_____
	6.		_____
	7.		_____
	8.		_____
9.	_____		_____

12.	_____		_____
	13.		_____

Clues:

1. These organisms can produce their own food.
2. This group of organisms recycles nutrients by breaking down dead organic substances.
3. The study of the three general types of relationships we see in nature.
4. The living environment of an ecosystem is also call the _____ community.
5. The raw materials of "food"
6. An ecosystem is made up of the nonliving and the living _____ or surroundings.
7. All of the living and nonliving factors in a given space

8. In living systems, its source is the sun.
9. Plant eaters
10. Organisms that obtain their food from other sources
11. We want to avoid making this type of decision when we deal with marine ecology.
12. This group of organisms uses sunlight to manufacture food from simple organic molecules.
13. Meat eaters

TEACHER BACKGROUND - Ecology of Puget Sound

"Ecology of Puget Sound" serves to reinforce some of the ecological concepts introduced in "Marine Ecology" through a look at a specific area, the Puget Sound. For the vocabulary and concepts of ecology to become incorporated into the vocabulary of your students, frequent repetition and reinforcement is necessary. It is important to train your students to begin to look at the "whole picture". They need to look at the effects of a given action on the system as a whole rather than just on the specific factor altered by the action. Puget Sound is a unique area and has been recognized as such since the earliest days. In 1841, Captain Charles Wilkes gave us a graphic picture of the area writing:

"I venture nothing in saying that no country in the world possesses waters equal to these. From the mouth of the straits to the head of navigation 200 miles inland, not a shoal nor reef nor hidden danger exists. At times it narrows to a river's width and again widens into the majesty of a sea, but is free to navigation, the home of all craft; blue, deep and fathomless."¹

Puget Sound possesses a great variety and abundance of seashore life due to the great diversity of habitats found within the Sound. Rocky shores, reefs, tide pools, boulders, sandy beaches, quiet bays, muddy bottoms, and changing estuaries are all found within this area. Marine plants flourish and all of the animals of the food chains of the sound benefit as a result of the lush plant growth. It is important to remember that every organism requires certain elements from the environment. An organism can only tolerate limited change within these elements and still survive. As such, it is common to find that each different habitat has its own characteristic association of plants and animals.

Physically, Puget Sound is one of the deepest salt water basins in the United States. Depths of 600-800 feet prevail in the northern portion. South of the Tacoma Narrows the depths shallow but are still considerable as 300 feet is typical. Deep holes occur in either area, illustrated by the maximum depth of 930 feet off Point Jefferson in the northern portion and a 546 foot hole near McNeil Island in the southern portion. The average depth is 205 feet. Fifty percent of the total volume of water lies below 25 fathoms. The basin is generally steep-sided.

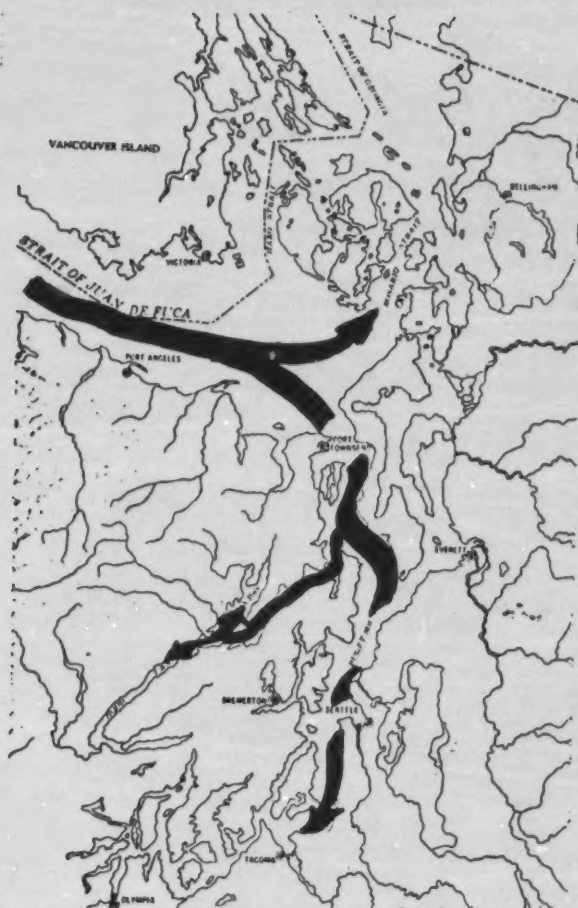
1. ENETAI, Vol. 1, No. 20



The total length of shoreline of Puget Sound proper is 1,157 nautical miles. Its volume at mean high water is 26.5 cubic miles. The average tidal volume is 1.27 cubic miles, an incredible volume of water to move twice daily!

The entire Puget Sound system lies within an area of about 40 x 90 nautical miles. The entry to Puget Sound is the Strait of Juan de Fuca, approximately 80 miles wide and 405 miles long. The strait of Juan de Fuca bisects the water mass of the State of Washington. Washington Sound lies in the north (including those waters south of Canada), and Puget Sound proper to the south. Washington Sound connects to the Strait by Haro Strait, San Juan Channel, and by Rosario Strait. The passes in the San Juan Archipelago are extremely narrow, resulting in turbulence and rather high velocity of tidal currents.

Puget Sound proper has been divided into four general sections which are partly isolated by vertical or lateral constrictions. Admiralty Inlet extends southward for 50 nautical miles and transports approximately 95% of all water entering or leaving Puget Sound. Water in the north end of Admiralty Inlet is extremely turbulent.



Water inflow along the Strait of Juan de Fuca strikes Whidbey Island, and becomes divided northward and southward. Admiralty Head deflects the flow westward into incoming water and large swirls and eddies result. Compounding this surface flow is turbulence generated from a submerged threshold sill at a depth of 240 feet. This sill deflects incoming and outgoing water upward. Added to this are winds, often 10 - 20 knots, occasionally 25 - 40 knots, channeled along the fetch (surface) by paralleling mountain ranges. Currents of 5 - 6 knots in Admiralty Inlet are common. The main basin of Puget Sound extends from the threshold sill to a sill 156 feet deep at the Tacoma Narrows. The latter location is also in an area of very fast currents and considerable turbulence. The section south of the Narrows consists of a 600 foot deep basin with many branching channels and inlets. The third section is Hood Canal, a fjord about 50 miles long and 2 miles wide, separated from Admiralty Inlet by an outer sill 165 feet deep and an inner entrance sill 180 feet deep. Water between the two sills is extremely turbulent, aided by winds channeled by the steeply rising land surface. Depths in Hood Canal average 400 - 500 feet. Maximum

depth is 600 feet. The fourth section lies on the east side of Whidbey Island and drains out through Deception Pass. These waters are shallow with marshes and mud flats conspicuous in many sections.

The continental shelf near the entrance to the Strait of Juan de Fuca is cut by a submarine valley which extends in a southwesterly direction and traverses the entire width of the shelf. The valley is about 4 miles across with a floor about 1,000 feet below the level of the shelf. This valley is the access of a great volume of deep cold water to the surface at the entry to Puget Sound.

In general, water temperatures are cold with relatively little seasonal fluctuation. Seasonal changes are minimal owing to wind and tidal related turbulence. Only in protected shallow water areas are extremes of temperature observed.

Usual surface salinities vary from 31.89 parts per thousand (o/oo) 200 miles west of the Strait of Juan de Fuca, to 29.81 o/oo in the Strait, to 28 - 30 o/oo in Puget Sound. There is little seasonal change, probably due to water turbulence and mixing. However, in Hood Canal where tides and currents are sluggish and where a massive amount of fresh water enters in spring owing to snow melt from the Olympic Mountains, surface salinities have been recorded in the spring as low as 8.0 o/oo. This fresh water layer extends to a depth of 20 feet. In summer and autumn Hood Canal salinities approach those of Puget Sound. These extreme variations cause the Hood Canal to have a different species composition of plants and animals than other sections of Puget Sound.

The tides of Puget Sound are of the mixed type with a marked diurnal inequality. The tidal range becomes progressively greater landward from the entrance. In the Strait the diurnal range of tides is 8 feet, at Seattle it is 11 feet, while the inlets at the southern extremities display a 15 foot diurnal range.

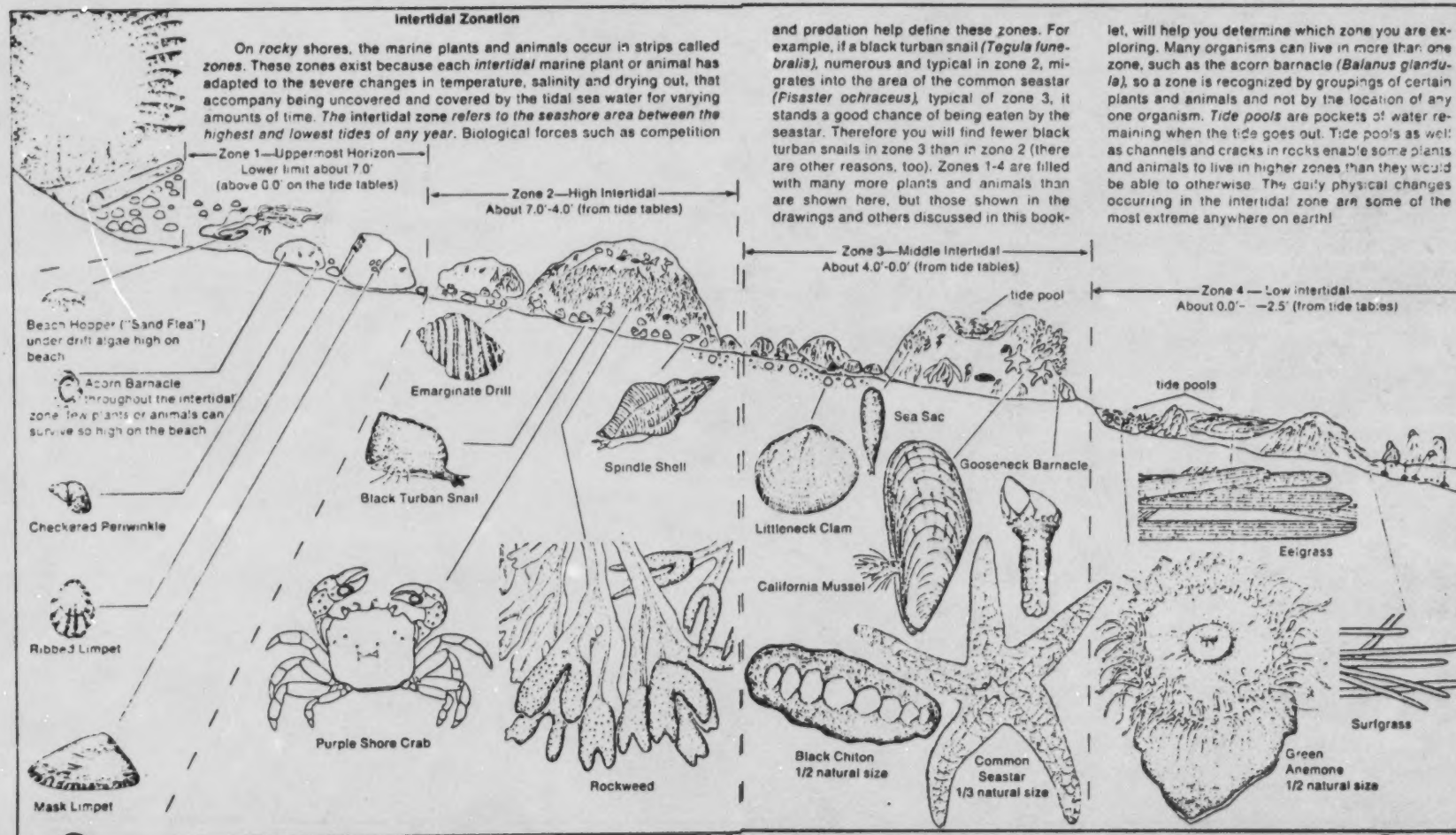
The climate of the region is predominately maritime, with prevailing southwesterly onshore winds accompanied by heavy precipitation from autumn to spring. During winter the area is influenced by a large low pressure cell centered over the Bering Sea. In summer considerable air flow is from the northwest and north and little precipitation occurs. The Seattle area receives approximately 36 inches precipitation per year. West of the Olympic Mountains, rainfall increases to 144 inches per year in some areas.

Air temperatures are mild. In summer, air temperatures do not often exceed 80° F.

Puget Sound represents the boundary delimiting the North Temperate Region and the Lower Boreal Region. These regions are temperature zones based on an attempt to correlate observed marine plant distribution with temperature. As a result the Puget Sound area contains a greater variety of organisms than might normally be expected. It is an interesting area biologically as some organisms reach their most northerly point of distribution and others attain their most southernly point of distribution in the area. The Puget Sound region supports an abundance and variety of large brown algae commonly called "kelp". Owing to their growth form and dominance in the habitat, these algae are controlling factors in the presence or absence or development of other plants and animals. They are attached to the substrate by large holdfasts. The kelp occupy a large amount of space and cast a rather large amount of shade. The most conspicuous green algae in Puget Sound are members of the Ulvaceae (sea lettuce), and the Cladophoraceae. The red algae have two basic forms. One is a highly branched habit. The other is a large sheetlike thallose form. Both forms are well adapted to the turbulent water. Water moves with relatively little friction through the branched plants, while the thallose red are tough and rubbery but pliant. The thallose algae which seem to resist drying, often fall over the smaller more delicate branched reds, thus protecting them from desiccation (drying) at low tides.

Within Puget Sound, organisms are limited in their growth by a complex of environmental conditions, e.g., tidal range, surge and wave splash, water clarity, availability of firm substrate, atmospheric humidity, and to a lesser degree, salinity. Generally, intertidal zonation in Puget Sound is striking, with one exception. There is little intertidal life in Hood Canal, probably due to the coincidence of the extreme dilution of salinity by snow melt with the period of spore settling and germination.

Conspicuous in the intertidal zone are bands of colonial Ulvaceous green algae, blackish colored red algae, and lighter colored red algae close to the low tide line. Below the low tide line seagrasses, kelps, red algae and coralline red algae are conspicuous. Among the more common animals are snails, limpets, barnacles, and crabs in the intertidal, with starfish, sea urchins, crabs, fish and a host of detritus feeders such as sea cucumbers, and sea pens in the sublittoral.



Eelgrass (Zostera marina) is an important species in areas with muddy substrates. The interrelationships that exist in an eelgrass community are explored in the student text. Eelgrass is one of the most productive plants on the face of the earth. It is also one of the plants facing widespread destruction as man alters the fragile ecosystems of the coastline. Since this ecosystem supports the developing stages of many deep and shallow water fish and shellfish, the destruction of these areas has a widespread negative impact.

Duplicate the text pages. One set is recommended per student. This activity may be performed by individuals in class or as homework assignments. The answers to the questions may be found within the body of the text. It is also possible to have small groups work together to answer the questions. Use the approach that will work best with your particular class. Allow some time upon completion for discussion of the answers and the concepts involved therein.

KEY

- 1. If Puget Sound was a rectangle with the size of 40 x 90 nautical miles, the total shoreline length would be the perimeter of the rectangle or 260 nautical miles.
2. The difference between the theoretical shoreline of 260 nautical miles and the actual shoreline of 1,157 nautical miles tells us that the shoreline is highly irregular with many bays and inlets which contribute to the large shoreline area.
3. As skipper of the Peter and Paul you would pass through southern Puget Sound, Tacoma Narrows; Central Puget Sound, Admiralty Inlet and the Strait of Juan de Fuca before reaching the open ocean.
4. There are many environmental factors besides temperature that can limit where an organism can survive. For example, oxygen concentration, salinity, predators, food supply, suitable substrate for attachment, pH, etc. can be limiting factors. You might want to list the suggestions from your students on the board and then group them into categories such as physical factors, biological factors and/or chemical factors. Every organism is subjected to a variety of environmental factors, some more critical than others, but all influence the success of the organism.

5. The two major hardships faced daily by plants and animals living within the intertidal zone are drying and increased temperature. Other factors include: ultraviolet radiation, predation, and suffocation due to reduced oxygen availability because of the reduced possibilities of gas exchange.
6. Several animals are found in more than one zone: sea urchins, hermit crab, and shore crabs.
7. Polychaete worms, and clams are shown among the rhizomes of the eelgrass.
8. Ten animals are shown living on the leaves, seven are on the mud surface, one kind among the leaves, and two kinds are found in the mud.
9. None of the animals shown are found in more than one of the habitats mentioned in number 8. The habitats, though close in distance, are different enough ecologically to have entirely different associations of plants and animals.
10. If eelgrass beds are further reduced in size we can expect the populations of animals such as crabs and scallops to also decrease and to perhaps disappear. This is a good point to briefly discuss shoreline development. Eelgrass beds are often found in shallow areas suitable for dredging and filling. As such, these areas are particularly susceptible to destruction.

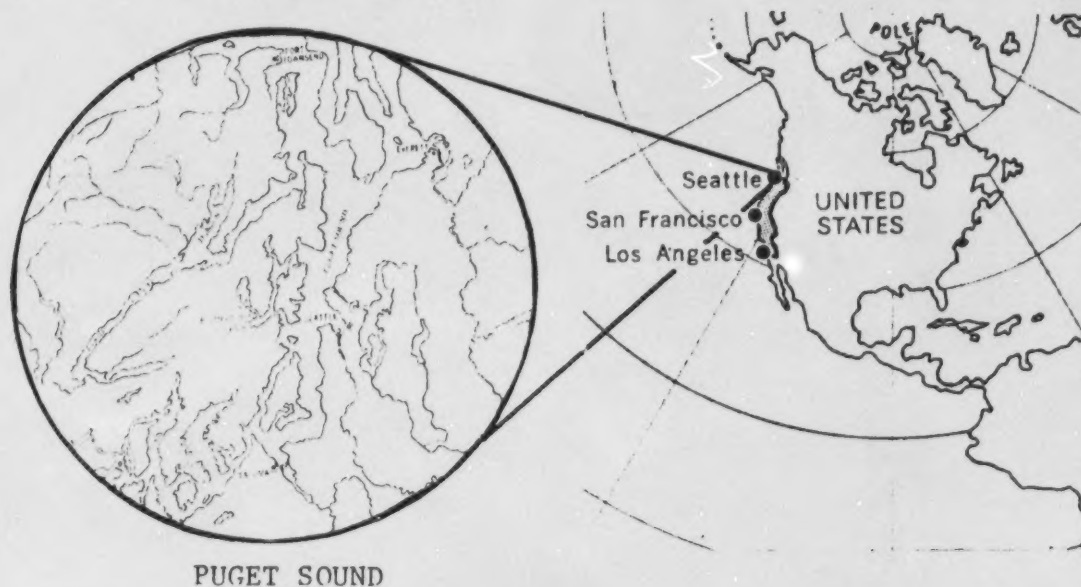
KEY WORDS

detritus
food chain
grazing
herbivores
intertidal zone
latitude
nautical miles
photosynthesis
rhizomatous
rhizome
sound
zonation

ECOLOGY OF PUGET SOUND

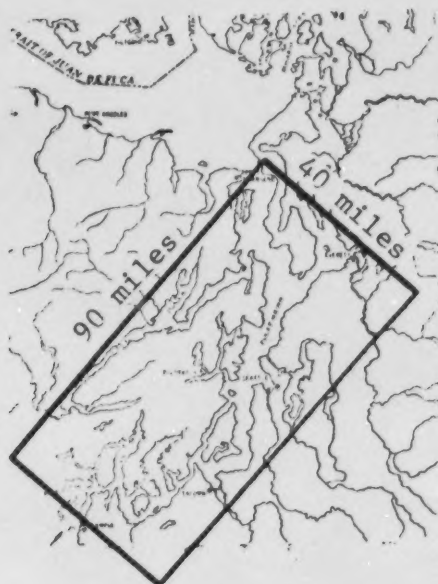
PUGET SOUND

Puget Sound lies in the northeast Pacific between 47° North latitude and $48^{\circ} 30'$ North latitude. The sound is a large inlet or arm of the sea. It is one of the deepest salt water basins in the United States. The average depth is 205 feet while the deepest spot is 930 feet off of Point Jefferson in the northern portion of the sound. Fifty percent of the total volume of water lies below 25 fathoms (150 ft.) which indicates that the Puget Sound has a steep-sided basin.



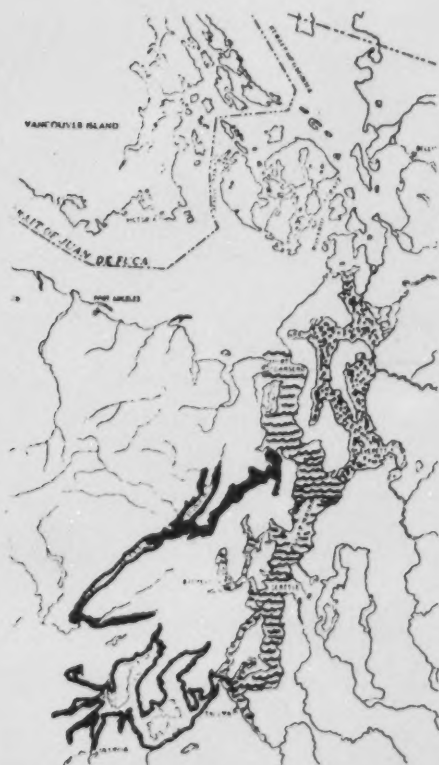
Puget Sound lies within an area of about 40 x 90 nautical miles. The total length of shoreline is 1,157 nautical miles and its volume at mean high water is 26.5 cubic miles.

1. If the Puget Sound was a rectangle with the size of 40 x 90 nautical miles, what would the total length of the shoreline be?



2. The actual shoreline is 1,157 nautical miles. What does the difference between the theoretical shoreline (that of the rectangle) and the real shoreline (1,157 nautical miles) tell us about the shoreline?

The entrance to Puget Sound is through the Strait of Juan de Fuca into Admiralty Inlet. The passes are extremely narrow and the tidal currents move rapidly in these areas. Sailing ships of old were often lost in these sometimes treacherous waters. Central Puget Sound extends south of Admiralty Inlet to the Tacoma Narrows an area of fast currents and considerable turbulence which forms the entrance to the Southern Puget Sound. Two major divisions of the Puget Sound System remain: The Hood Canal and Possession Sound. Hood Canal is a fjord about 50 miles long and 2 miles wide. Depths in Hood Canal average 400 to 500 feet. Possession Sound, the last section, lies on the east side of Whidbey Island and drains out through Deception Pass. These waters are shallow with marshes and mud flats conspicuous in many sections.



-  Puget Sound
-  Southern Puget Sound
-  Hood Canal
-  Possession Sound

3. As skipper of the Peter and Paul you are ready to sail from your home port at the very southern tip of Puget Sound out into the open ocean bound for the albacore tuna of the open ocean. List the subdivisions of the sound through which you would sail on your way to the open ocean.

Water temperatures in the Puget Sound are cold with relatively little seasonal fluctuation. The only exceptions are to be found in shallow water areas where summer and winter water temperatures may vary by as much as 14° C. The water temperatures in Puget Sound are cold enough for animals found far to the north in Alaska to survive and also warm enough for animals found far to the south in Mexico to also survive. This area represents the northward extension of the range of many southern animals and plants and the southward extension of many northern animals and plants.

4. Temperature is an environmental factor that can limit where an organism can survive. What is one other environmental factor that can limit where organisms can live?

Within Puget Sound, organisms are limited in their growth by a complex of environmental conditions: tidal range, surge and wave splash, water clarity, availability of firm substrate on which to attach, atmospheric humidity and salinity. The environmental conditions found in the intertidal zone tend to cause a zonation of plants and animals. Certain kinds of plants and animals are found at specific distances from the low water line.

5. What are two hardships faced daily by animals and plants living in the intertidal zone?
6. Is one kind of animal found in more than one zone? (from picture) If so, which one?

The interactions between the plants and animals in any area are complex. Let's look at the relationships that exist in an area with a mud bottom. The estimated quantity of eel grass which grows in Puget Sound is 24 million wet tons (wet ton is the weight during growth). This eel grass supports 18,000 tons of food fish (perch, flatfish, herring) and 5,000,000 tons of wildfowl (geese, ducks). Eel grass is an important contributor to the productivity of Puget Sound. Eel grass, Zostera marina, has a very fundamental role in colonizing and stabilizing an otherwise muddy substrate (bottom). Few marine plants can grow on a muddy substrate. Eel grass has developed rhizomatous (root-like) holdfasts which will anchor the plant in the mud. Their extensive rhizome system is located in the substrate while the leaves extend upward into the water mass. Since eel grass grows in both of these places, a diverse group of plants and animals can live in association with the eel grass. Eel grass supports four groups of animals: those on the leaves, those that swim among the leaves, those on the mud surface and those which burrow into the mud.

Intertidal zonation in Puget Sound is striking, with one exception; there is little intertidal life in Hood Canal. Lack of intertidal life may be due to the timing of the snow melt. The fresh water reduces the salinity and prevents the algae from reproducing. Since algae form the basis of life in the intertidal zone, all life is affected.

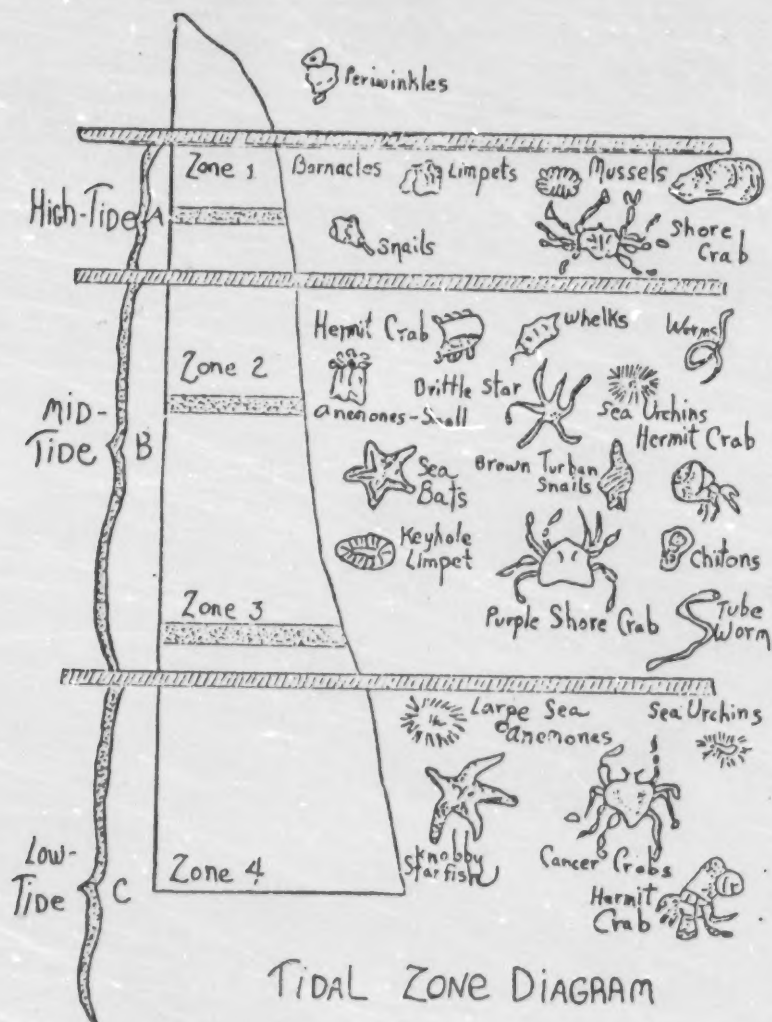
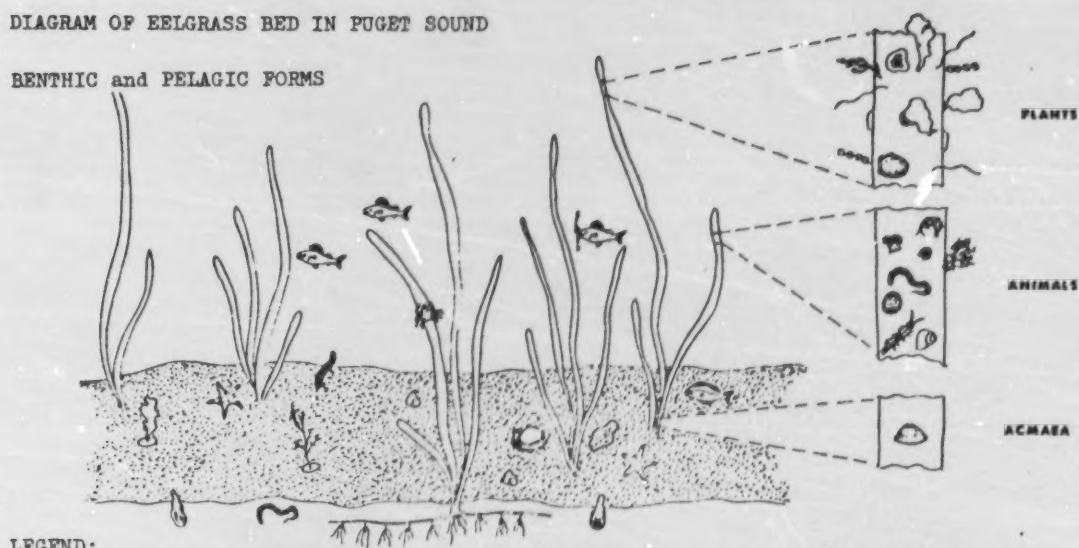
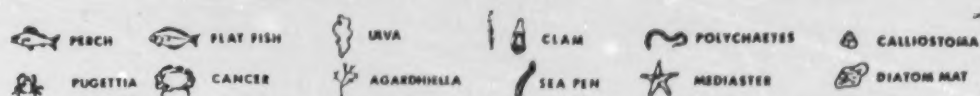


DIAGRAM OF EELGRASS BED IN PUGET SOUND

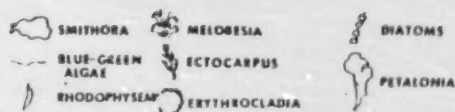
BENTHIC and PELAGIC FORMS



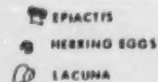
LEGEND:



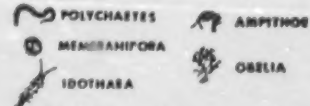
PLANTS:



EPIPHYTES



ANIMALS:



7. Which animals are found among the rhizomes of the eel grass?
8. How many different kinds of animals are shown living on the leaves? On the mud surface? Among the leaves? In the mud?
9. Are any of the animals found in more than one of the habitats mentioned in number 8?

The fundamental role of eelgrass is as a base for a food pyramid culminating in several species of food fish. The importance of eelgrass in the mud bottom ecosystem was shown in the 1930's when a widespread "wasting" disease decimated up to 99% of the eelgrass stands along the Atlantic coast of the United States and Europe. With the disappearance of eelgrass,

commercial species of fish, lobsters, clams, scallops and many other animals declined or disappeared. Populations of certain waterfowl, which depend upon eelgrass for their principle food, declined severely. The disappearance of the eelgrass affected all of these other organisms because they are all interrelated; what affects one, affects all.

How were all of these organisms affected? The value of eelgrass is not in its direct use by herbivores (plant eaters). The value lies in its role as a source of detritus (plant debris from dead and dying parts) for a host of detritus feeders which are present in eelgrass beds. Many of these detritus feeders are commercially important, such as crabs, clams, scallops and lobsters. Thus, food chains based on detritus and not on grazing are most important in eelgrass beds. Eelgrass is exceeded by only a very few plants in the net daily production of plant material via photosynthesis. Unfortunately, eelgrass beds are often near the shore and have suffered by man's landfilling activities.

10. Eelgrass beds are important areas for the spawning and growth of animals such as crabs, and scallops. What will happen to the populations of these animals if the eelgrass beds are further decreased in size?

TEACHER BACKGROUND - The Ecological Niche

In "The Ecological Niche", each student will have the opportunity for an in-depth exploration of a marine animal of his/her choosing. Stress the concept that organisms have evolved special adaptations that allow them to survive in specific areas and that these organisms require certain things from their environment for survival. In other words, plants and animals live where they do because they find their essential needs met within the confines of that area. This exercise reinforces some of the material covered previously while allowing the student to bring together seemingly unrelated items in the study of a single animal.

Duplicate the activity pages. One set is recommended per student. This exercise is best utilized as an individual activity. Upon completion, you might find it profitable to have your students exchange papers and provide written comments on the papers they receive. Some of your students may need help in selecting animals. Provide ample reference books and magazines to aid in their selection and to help provide answers to the activity questions. A trip to the library might be in order here. It is possible to assign this activity as homework, but most classes need at least some initial guidance in attacking the questions. Allow some time for a discussion of the answers. The discussion may be facilitated by constructing a large food web on the blackboard using the animals selected by your students.

KEY

The answers will depend upon the animals chosen. Be aware of overly creative answers with no basis in fact. Also, not all questions apply to all animals.

KEY WORDS

anemone

carnivore

commensalism

ecological niche

food chain

herbivore

high tide zone

host

interrelated
intertidal zone
low tide zone
mid tide zone
mutualism
omnivore
parasite
plankton
predator
prey
relationship
salinity
scientific name
substrate

THE ECOLOGICAL NICHE

In Puget Sound and in the oceans in general, plants and animals live where they do because they can. This seems like a strange thing to say but if we stop to look at the statement we can learn a great deal about ecology. Each plant or animal has certain essential requirements that must be fulfilled for its existence. The plant or animal will not be found in areas where one or more of these requirements is missing. Any time we find a plant or animal living in an area, we can assume that its essential requirements are being provided by that area. The organism lives where we find it because it can live there because its life needs are met. Let's look at an example. The Sun Anemone is found growing attached to pilings in many areas of Puget Sound.



Sun Anemone (Metridium marginatum)

What are some of the Sun Anemone's most essential needs? We might list them as follows:

1. food supply (plankton organisms)
2. attachment substrate (proper bottom)
3. proper water coverage (tidal level)
4. proper oxygen (O₂) amounts

5. proper salinity
6. protection against predators, etc.
7. proper water temperatures
8. interrelation with other animals

The Sun Anemone will only be found in areas which supply the correct amount and the proper relationships of these items. If one item is missing, the sun anemone is also missing. Each plant or animal is restricted to a particular ecological niche, those conditions and relationships with which the animal or plant can survive.

In the exercise that follows it will be your task to define the ecological niche of a marine animal of your choice. To help you define the niche, answer the following questions as completely and in as much detail as you can. You may use reference books, magazines, direct observation, or any other aids to help you come to your conclusions.

1. Common name _____
2. Scientific name _____
3. This animal is a (circle the correct answer)...

Herbivore
Carnivore
Omnivore
4. The type of food it specializes in eating is _____

5. Describe how the animal obtains its food. _____

6. Beginning with marine plants, trace the path of energy from the plants to the animal you have chosen. Draw a food chain showing this path of energy transfer.

How many links on the food chain does the energy pass through before the animal you have chosen can use it?

This would make it a _____ consumer.

7. What are the specific predators of this animal? _____

8. How is the population of your animal's species kept in check?

9. Name the animals that are predators on your animal. Predators kill quickly and consume the "victim" (prey) whole or in part.

10. Other kinds of relationships besides predator-prey relationships exist between animals. For example: Parasite-host relationships occur in which one type of organism (the parasite) lives on or in another living organism (host) and obtains their food from them. The parasite is benefited by the relationship while the host is harmed. Mutualism

and commensalism are terms used to describe other types of relationships. In mutualistic relationships, both organisms benefit from the close relationship. In commensal relationships one animal derives benefit while the other is unharmed. What kinds of animals are parasitic, commensal, or mutualistic with your animal? Be specific and name the type of relationship observed.

11. If your animal spends most of its life attached to something describe the exact bottom type on which it is most commonly found.

12. If your animal lives in the intertidal zone, describe where it is found: high tide zone, mid tide zone or low tide zone. The high tide zone is found at the extreme upper limit of the tidal wave wash. It is exposed to more air than water. The mid tide zone is found at the level of the higher low tides. This area is not exposed to air by all tides. The low tide zone is exposed to more water than air. It is only exposed to the air during extreme low water tides.

13. Describe the current action, water temperature range, salinity range and any other special water conditions your animal needs for survival.

14. Putting all your information together, predict very carefully and completely what would happen if this species was eliminated from an area.

15. How can we say that all plants and animals are interrelated in the ocean ecosystem?

TEACHER BACKGROUND - Wharf Rat

"Wharf Rat" is a field exercise that may be accomplished on most pilings that have been subjected to tidal water changes for at least a year. This activity provides a first-hand look at intertidal zonation. As the tides rise and fall, the organisms living on the piling are subjected to various environmental hardships. Because the hardships differ from one spot on the piling to another, we find that the animals and plants also differ from one spot to another. The changing water level produces different habitats and the different habitats support different kinds of plants and animals. As is often the case, the real world and the theoretical do not always coincide. Because of local variations in the environmental conditions and because of the inherent variability of plants and animals, the intertidal life zones may be difficult to distinguish. The divisions may simply not be distinct.

Prior to duplicating the materials for this activity, you will need to locate: (1) a suitable pier or wharf with partially submerged pilings and (2) a tide table. Low tide is necessary since the pilings will be underwater on high tides. Suggest that your students wear rubber boots or waders. One set of duplicated activity pages per student is recommended. Please refer to the introductory pages for some precautions regarding the observation and collection of marine animals and plants. Strive to have your students "leave only footprints and take only memories." Some of your students may have difficulty in estimating the number of organisms in each zone. Help them with the sampling procedure and in the calculations necessary to estimate the total population from the sample size. To save your identification books, you might duplicate the pages that contain descriptions of the animals and plants most common in the area studied. The common animals and plants can be determined on a recommended preview field trip. The strip transect technique used in Part B is readily understandable in theory. In practice, your students may need some encouragement to actually count all of the organisms within the strip. Be alert to any students who give up early and provide them with the encouragement needed to continue. Some may find it difficult to mark and measure the strip. You might suggest that they use a piece of paper or a card with a five centimeter long line or a 5 centimeter wide notch 2 centimeters deep near the edge. They can then move the paper down the piling calling off the numbers of each organism as they appear within the 5 centimeter

space. This exercise is best accomplished in small groups although the "analysis and interpretation" section lends itself to individual completion. You may need to give some assistance in the graphing of the materials. Provide the aid that your class requires for successful completion of this activity.

This activity may be expanded in a number of ways. It is particularly enlightening to have your students do a transect at each of the four "sides" of the pole (eg. north, south, east, west). The results can be compared to determine differences present.

KEY

Data on the "Data Sheet" will depend upon the location chosen. If the pilings used by different groups from your class are close to each other, you might expect the results to be similar from one group to the next.

Analysis and Interpretation

1. While the specific results depend upon the data obtained, it is unlikely that all of the results are the same. There are two major classes of factors that might cause the differences: observer error or actual environmental differences. Your students may suggest sources from either of these classes. For example, differences in wave exposure, water depth, location, etc. might be environmental factors that could be responsible for the differences. Errors in measuring the height, in recording, in defining the limits, etc. would be considered as observer error. Your discussion of this question might be accompanied by a list on the blackboard which separates the factors mentioned into the two major categories discussed above.
2. The answer depends upon experimental results.
3. The answer depends upon experimental results. It is unlikely that the animals occurred in the same number at each level. Factors such as the length of time exposed to air, changes in temperature from level to level during tidal changes, food availability, oxygen levels, etc. would help explain a difference in the numbers from zone to zone.
4. There are many environmental factors that might limit a species' extension into the upper tide zone. Extremes in temperature, high when exposed, low when submerged; exposure to the air for long

periods; drying; suffocation; battering by frequent and often strong wave action; insufficient water movement to remove wastes; etc. are factors that might limit a species' upward extension.

5. Some of the environmental factors which limit upward extension may also limit downward extension of a species' range (e.g. temperature tolerances). In addition, presence of predators, nearly permanent submergence, and lack of proper food are factors that might limit a species in its downward extension. It is interesting to note, that often species are able to live quite well under the conditions found on other parts of a piling yet they are not found on the other parts. The explanation lies in the fact that while they are able to survive in these other locations, other animals can survive better and these other organisms out-compete the species trying to extend its territory. The living environment, then, has a pronounced effect on where an organism can live.
6. The answer depends upon the organisms chosen. While the protective adaptations may be gleaned from the pages of a book, encourage your students to use their observational powers to answer this question.
7. The major food source for piling animals is water-borne plankton. Most piling organisms are sessile (attached and non-moving) and wait for their food to come to them.
8. Oil and gasoline slicks are particularly devastating to piling organisms since the changing water levels allow the slick to coat a large area of the piling. This is not to say that other forms of pollution including heavy metals and hot water have no effect.
9. The tide is an important environmental factor because it directly causes the alternate wetting and drying of the piling organisms. It also indirectly causes the piling organisms to be subjected to changes in temperature and ultraviolet radiation. Some of the other environmental factors include: Oxygen availability (indirectly influenced by the tides); predation; food availability; illumination; dissolved substances; pressure; water temperature; etc. For each factor, every organism has a given range within which it can survive. The interrelationships between these factors determine where an organism can live.

KEY WORDS

attachment
community
environmental factors
estimate
habitats
horizontal axis
intertidal life zones
organism
species' extension
strip transect
substrate
vertical axis
wharf piling

WHARF RAT

The changing water level caused by the tides produces many different habitats on a vertical wharf piling. Since animals and plants live where their environmental requirements are fulfilled, we might expect to see different kinds of organisms in the different habitats found on one piling. Often different organisms are found in specific bands which correspond to the different habitats. It is not always easy to distinguish the intertidal life zones on a wharf piling. In this activity you will have a chance to explore the zones and to sample, identify, measure and analyze some of the species located on a wharf piling.

Materials:

meter stick

identification books

clip board

rubber boots

tide table

Procedure:

Part A - Determining Zones

1. Examine your piling carefully. Divide your piling into three sections by finding differences in the plants and animal communities of the piling. The top section is the high tide zone. This area is found at the extreme upper limit of the tidal wave wash. It is exposed to more air than water. The second section from the top is the mid tide zone. This zone is found at the level of the higher low tides. This area is not exposed to air by all tides. The lowest section is the low tide zone. This zone is exposed to more water than air. It is only exposed to the air during extreme low water tides. Starting at the bottom, use your meter stick to measure the width of each band. Record the width of each band on the drawing of the wharf piling.

2. Examine the low tide zone for evidence of two sections relating to low and extreme low tide. Mark each of the sub-sections on your drawing.
3. Use your books to identify the organisms found in each tidal zone. Record their names and their method of attachment to the piling on your data sheet.
4. Estimate the number of organisms within each zone and record on your data sheet. (Hint: count the number in a small area of known size and estimate upward to the whole area using this information).

Part B - Strip Transect

1. Choose two animal species found on your wharf piling. Beginning at the highest point of your high tide zone, measure a 5 centimeter wide strip down the piling until you run into the substrate (bottom). For each tidal zone, count all of the animals (of the two species chosen) that are within the strip. Record these numbers on your data sheet. This method is called a strip transect and is useful in estimating animal numbers.
2. Show the abundance of each animal graphically. Use the graph paper on your data sheet to construct a single graph. Label the vertical axis "Number of Animals". Label the horizontal axis "Tidal Zone". Use two different colored lines or a dotted and solid line to show the changes in the number of each animal with changes in zone. Be sure to give your graph a title and indicate which line represents which animal.

Analysis and Interpretation:

1. Compare your results with those of others in your class. Were all of the pilings divided at the same depth? If not, what are two possible sources of the differences observed?

2. Which zone had the most organisms? What are two possible reasons that might explain why this zone had more organisms than the others?

3. Were the two animals you chose found in the same number at each level? If not, at which level was each most numerous? What is one environmental factor that might cause a difference in the number of organisms from level to level?

4. What are two environmental factors that might limit a species extension into the upper tide zone?

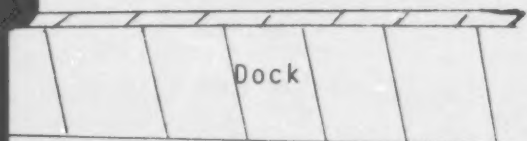
5. What are two environmental factors that might limit a species extension into the low tide zone?

6. Pick one organism from each zone and describe how it protects itself from drying at low tide and also from winter storms that may occur during low tide.

7. What is the major food source for piling animals?

8. What types of environmental pollution are particularly devastating to piling organisms?

9. The tide is perhaps the most important environmental factor affecting piling organisms. How does the tide affect piling organisms and what are four other environmental factors that are important to the survival of this community?

DATA SHEET

1, 2

3. High Tide Zone
Name

Attachment

Mid Tide Zone
Name

Attachment

Low Tide Zone
Name

Attachment

Substrate

4. Number of organisms = $\frac{\text{number in small area}}{\text{small area}} \times \frac{\text{number of small area}}{\text{in zone}}$

High Tide = _____

Mid Tide = _____

Low Tide = _____

WHARF RAT

DATA SHEET

Part B

1. Strip transect

Number of

(animal 1)

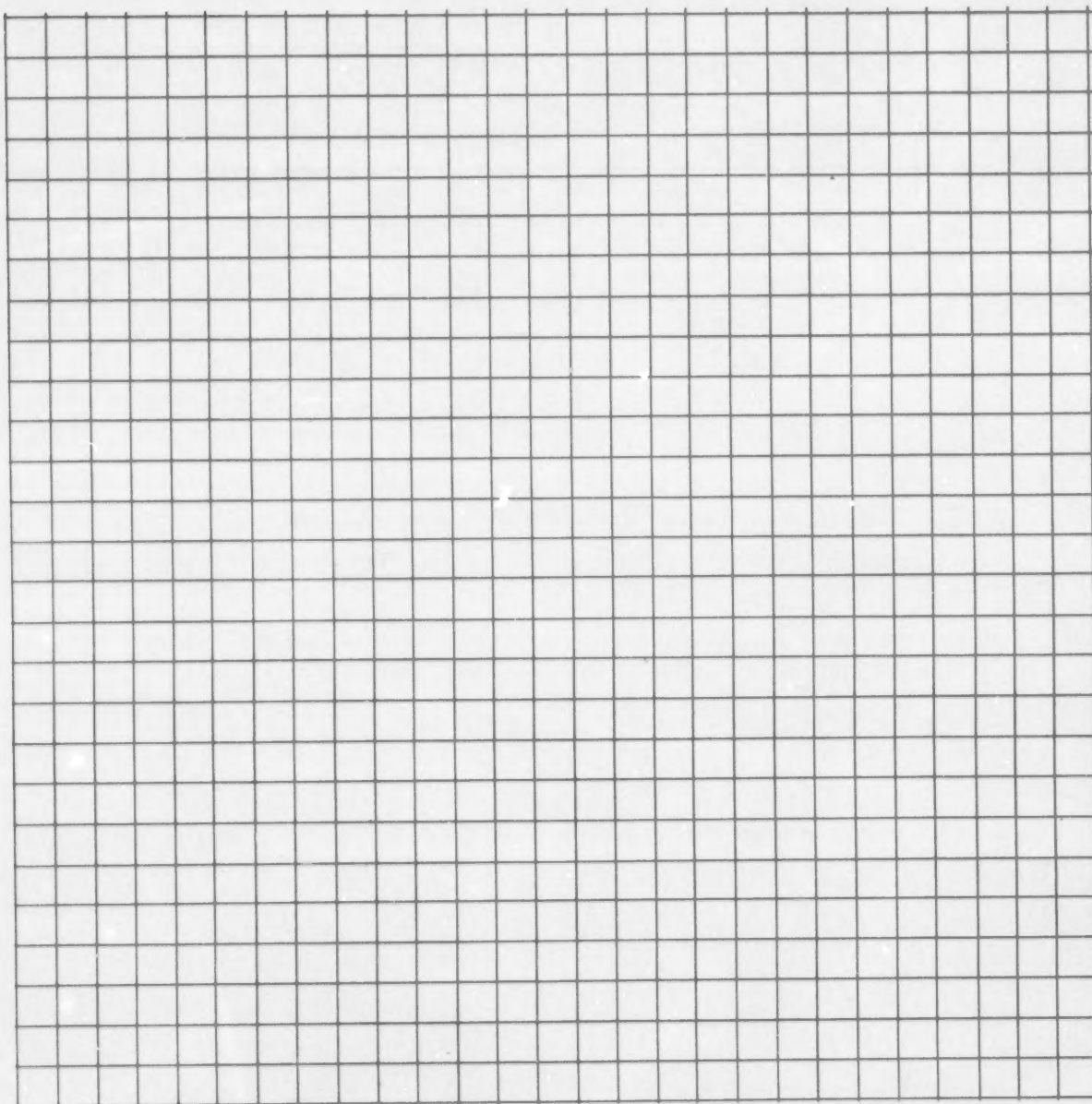
Number of

(animal 2)

High tide zone

Mid tide zone

Low tide zone



BIOLOGICAL FACTORS:

Microscopic Forms - Marine Bacteriology

TEACHER BACKGROUND - Microscopic Forms: Marine Bacteriology

"Microscopic Forms: Marine Bacteriology" is a complex investigation but it is worth the effort. The benefit comes more from appreciation than from specific knowledge. The activity provides a good test of the degree to which your students have learned to understand and follow directions, to work together in teams and to analyze the outcomes of their experimentation. The activity also provides a test of your ability to master laboratory logistics. Considerable materials are required. Check your supplies beforehand and organize your groups in such a way that your materials will suffice. Each class of 30 requires 90 test tubes, 90 petri dishes and 90 slides for team sizes of 4. If you have more than one class performing this activity, you might want to stagger the dates they begin so that you can reduce the materials required.

Duplicate the activity pages. One set is recommended per student. Circulate through the room as your students perform the activity. Anticipate any problem areas beforehand and move to eliminate them before they occur. Plan to devote a few minutes to a discussion of the results and to provide answers to the questions. While it is possible to have the students prepare the medium, it is more efficient to have one group prepare the medium for all or to prepare the medium yourself. Little learning is sacrificed since media preparation is a cookbook procedure. To prepare 60 culture tubes of 15 ml each requires the following materials:

Pipette, 10-ml

Test tubes, 18 mm x 150 mm, 75

Glass-marking crayons

Heat source

Distilled water, 1000 ml

Graduated cylinder, 500-ml

Beaker, 1000-ml

Balance

Stirring rod

Funnel, 4- or 5-inch

Ring stand and ring

Rubber tubing, to fit funnel tube

Pinch clamp or spring-compressor
clamp

Non-absorbent cotton

Wire test-tube basket or other suitable
container

Autoclave or pressure cooker

In addition to the above, each of the three media requires its own special ingredients:

Marine Bacteria Agar Medium

1 liter sterile sea water

10 grams peptone

15 grams agar

Marine Yeast Agar Medium

1 liter sterile sea water

20 grams agar

23 grams dextrose

1 gram Sol-U-Pro or equivalent protein

1 gram yeast extract

100 ml. Chloromycetin or Terramycin

Marine Mold Agar Medium

1 liter sterile sea water

17 grams agar

1 gram yeast extract

10 grams dextrose

100 ml. Chloromycetin, Terramycin, or penicillin

Procedure:

Using the pipette (or a small graduated cylinder), place 15 ml of water in a test tube and mark the water level with a glass-marking crayon. Pour out the water. Using this tube as a ruler, mark the 15 ml level on enough tubes to provide 4 for each team. Heat the water to just below boiling. (If the tap water bears no unusual amounts of dissolved minerals, it may be used in place of distilled water). Dissolve the agar first; then add the other ingredients in order listed for that medium. Heat until the mixture comes to a boil, stirring continuously. For dispensing the prepared medium into tubes, attach a short piece of rubber tubing to the stem of a large funnel and place a pinchcock on the tubing. Support the funnel on a ring stand at a convenient height. While the liquid is still warm (about 55° C), pour it (a portion at a time) into the funnel. A little practice in using the pinch clamp facilitates filling the marked tubes. Clean the dispensing apparatus between mediums. Plug the tubes with non-absorbent cotton. Place all the tubes in wire baskets, and sterilize in an autoclave or pressure cooker at 15 lb. pressure for fifteen minutes.

It is recommended that you demonstrate all steps in the procedure. This will provide your students with an overall view of the technique. It is desirable that the cultures be incubated at an even temperature. Generally room temperature is sufficient, but you may use a bacteriological incubator if you desire to maintain a higher and more even temperature. Be sure to include a container of water to maintain the humidity in your incubator should you decide to use this approach. Adjust the incubator temperature to 27° C.

This exercise is designed to take 3 or 4 class periods. The exercise on luminescent bacteria can be run concurrently by extending the time to 5 days + 1 day. Plan your starting date with these time requirements in mind.

Although the bacteria being cultured are ordinarily harmless, sterile procedure should be observed through the work, not only because the demonstration of

safe handling of microorganisms is one of the purposes of the investigation but also because it is possible for pathogenic organisms accidentally to get into the medium and multiply. Therefore, at the end of the work all tubes and petri dishes must be sterilized at 15 pounds for twenty minutes in an autoclave or pressure cooker before the medium is cleaned out of the glassware.

Additional information can be found in the references cited below. The procedure is involved, but the results in terms of student enthusiasm and learning justify the extra work.

KEY

Text questions

1. Three roles that marine bacteria play in the life of the sea include:
 1. The liberation of nutrients for plants by decomposing marine plant and animal remains (reduction of complex organic molecules into simpler ones more useable by plants);
 2. A direct food source for many small marine animals; and
 3. Bacteria help to determine the oxygen levels of sea waters.
2. If bacteria did not break down the complex organic compounds into simple compounds that can be used by plants, the plants would soon run out of the raw materials they require to grow and live. Without plant life, the animals would soon be without food (either directly or indirectly). The nutrients tied up in plant and animal wastes and carcasses would not be recycled. The whole nutrient cycling process would come to a halt and life as we know it would cease. The point to stress is that all life is interdependent.
3. There is considerable speculation over the benefits of bioluminescence. This question lets your students add their theories to the speculation. It is not certain that the light emission has a definite purpose (especially in the bacteria) but some hypothesize that it may be used as illumination or as a warning or attractant. In higher organisms, it may be used to attract members

- of the opposite sex or as species identification. You might ask your students to design experiments that might prove or disprove their hypotheses.
4. Sterile technique is required if one hopes to make statements about the origin of the microorganisms in question. To say that the bacteria came from the sand, we must minimize the chance that they entered with the water, or the air etc. Sterile technique also becomes important in protecting the investigator when she is dealing with pathogenic microorganisms.
 5. The number of microorganisms present in the original drop of water equals the number of colonies present on the agar plate. This, of course, assumes that each microorganism present in the water droplet was able to establish a colony.
 6. Since all of the members of a colony are descendants of one microorganism, in a single colony you would expect to find only one type of microorganism. An inoculating loop full of material from one colony, plated on a single agar plate results in a pure culture.

Analysis and Interpretation

1. Answer depends upon experimental results.
2. Answer depends upon experimental results.
3. The three media contain different compounds because each of the three groups of microorganisms (bacteria, yeast and mold) have different nutrient requirements. Each plate has a medium that favors a particular kind of microorganism.
4. The experimental intervention occurred to the other three plates; they were inoculated with the sea water from the sand solution. In theory, a control and an experimental plate should only differ by one variable; in this case the plating with the water from the sand solution.
5. Answer depends upon experimental results.

6. Many things can be cited as possible sources of the microorganisms found in the control. All of the sources reflect failures to maintain sterile technique. These include: unclean glassware, failure to flame mouth of test tube, contamination from air while the petri dish was open, etc.
7. Answer depends upon the experimental data. This question provides a check on the success of the sterile technique.
8. Any failure in sterile technique (for example, those cited above in question 6) could account for colonies in locations other than along the streaked path.
9. The points when contamination by microorganisms from other sources is most likely to occur happen when the petri dish is open during the pouring and streaking procedures or if the dish is opened to observe or count the colonies.
10. The microorganisms were most likely in the sand since the sea water used was sterile. The microorganisms may, however, have come from contamination in the ways mentioned above.
11. The roles played by these microorganisms include: 1. a direct food source for other marine animals; 2. reducing complex wastes and dead organism into simple compounds useable by plants; and 3. the determination of the oxygen levels of the water due to oxygen use by the microorganisms.
12. Their role as decomposers, breaking down dead animals and plants and wastes might help explain why they are so numerous in the sand. The detritus falls to the sand on the bottom.
13. Their role as decomposers and recyclers of nutrients is probably the most important in maintaining the life of the seas.

KEY WORDS

agar
autoclave
bacteria
bioluminescent
Bunsen burner
colony
contamination
control
convex
decomposing
detritus
erose
filamentous
food chain
inoculation loop
interface
lobate
microorganisms
molds
nitrates
nutrient medium (ia)
nutrients
organic
petri dish
phosphates
plate
plating out

pulvinate

punctiform

recyclers

reduce

rhizoid

role

sterile technique

streak

umbonate

undulate

yeasts

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A deserted beach or a liter of sea water appear to be without life. A close examination of these, however, will offer surprises. The abundance of life in beach sand or sea water is amazing. Many of the life forms are microscopic bacteria, yeasts and molds. Bacteria are especially widely distributed in the sea and on grains of beach sand. How are these tiny forms important to the life of the sea? What is their role?

Marine bacteria play an important role in the liberation of nutrients for plants by decomposing marine plant and animal remains. The bacteria reduce the complex organic molecules found in this detritus to simpler compounds like phosphates and nitrates that living marine plants can use for their growth. These microorganisms are the recyclers of the sea. The bacteria also serve as a direct food source for many small marine animals. Since bacteria use oxygen as they break down plant and animal wastes, they play an important role in determining the oxygen levels of sea waters.

1. What are three roles that marine bacteria play in the life of the sea?
2. What would happen to plant and animal life in the sea if bacteria did not break down the complex organic compounds into simple compounds that can be used by plants?

While marine bacteria are found everywhere in the oceans, the largest populations occur near the shore at the mud-water interface. In these areas the number of bacteria may range

from 50,000 to 400,000 bacteria per milliliter! Unlike terrestrial bacteria, most marine bacteria are colored. A considerable number are bioluminescent, they produce their own light, usually of a greenish hue.

3. What are two possible benefits of bioluminescence to bacteria?

In this activity, you will have an opportunity to observe the bacteria, molds and yeasts present in beach sand. While bacteria can be collected in water samples, the problems are more complex than collecting them in sand or mud samples. The bacteria sample you will use comes from a 2 centimeter deep by 30 centimeter square sand sample taken from the low tide line.

Since bacteria are found in the air, on your hands, and on the glassware you will use, certain special techniques will have to be followed to help ensure that the bacteria you grow actually are from the sand/sea water sample and not from your hands, etc. These procedures are commonly labeled "sterile technique" and you will follow them if you carefully read and perform the experimental section as it is written.

4. Why is "sterile technique" important in the study of bacteria?

The experiment you will perform involves plating out (smearing) a small drop of microorganism-containing water on to a surface which will provide the things necessary for the

microorganisms to grow. The surface is called a nutrient medium. Different kinds of microorganisms require different nutrient media. The nutrient medium, inside of the petri dish, is placed in an environment conducive to the growth of the microorganisms. If all goes well, the microorganisms will grow. Each single microorganism will multiply until it forms a colony of similar organisms that is visible to the naked eye. In other words, each colony that you see represents one microorganism present in the original small drop of water you plated out on the nutrient medium.

5. How could you determine the number of microorganisms present in the original drop of water?
6. How many different kinds of microorganisms would you expect to find in one single colony?

Sterile technique requires the use of a considerable amount of heat. Use care in the handling of equipment and materials. Remember: Hot glass looks the same as cold glass!!

Materials:

For each group of 4

- 12 sterile petri dishes or 3 oz. medicine bottles
- Bunsen burner or alcohol burner
- 12 slides and cover slips
- crystal violet stain 2%
- sterile sea water
- inoculation loop or sterile "Q-Tips"

grease pencil

2 test tubes

2 test tube stoppers

4 marine bacteria agar medium tubes (15 ml)

1 liter sterile sea water

10 grams peptone

15 grams agar

4 marine yeast agar medium tubes (15 ml)

1 liter sterile sea water

20 grams agar

23 grams dextrose

1 gram Sol-U-Pro or equivalent protein

1 gram yeast extract

100 ml Chloromycetin or Terramycin

4 marine mold agar medium tubes (15 ml)

1 liter sterile sea water

17 grams agar

1 gram yeast extract

10 grams dextrose

100 ml Chloromycetin, Terramycin, or penicillin

To prepare the media, follow the directions given by your teacher.

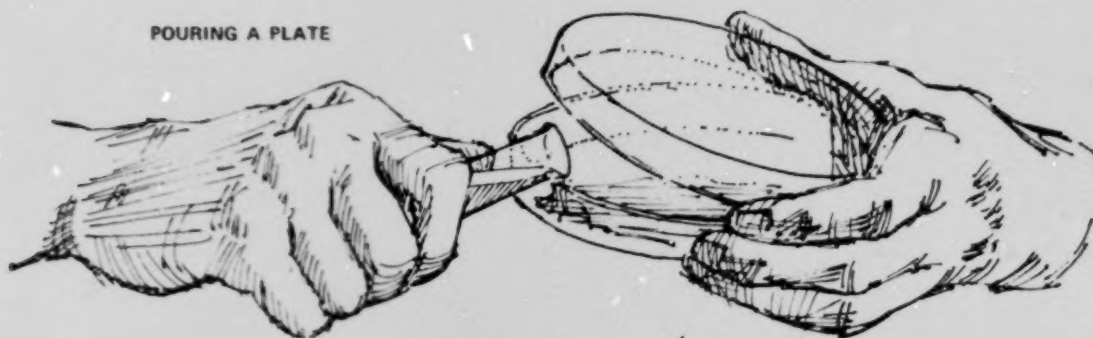
Procedure:

1. Each group member should prepare one petri dish or medicine bottle of each type of medium. Label petri dishes or medicine bottles with a grease pencil to denote the type

of growth expected: mold, yeast, or bacteria. Melt desired medium in the test tubes by placing them in boiling water. After melting, the tube is held in the right hand with the petri dish lid opened by the left hand. The lid is opened only enough to allow the mouth of the tube to be inserted and its contents emptied into the petri dish. The lid is then closed as rapidly as possible to prevent contamination. (See illustration below). Perform the entire process in a smooth flowing motion rather than in a hurried jerking motion.

Allow the media to harden.

POURING A PLATE



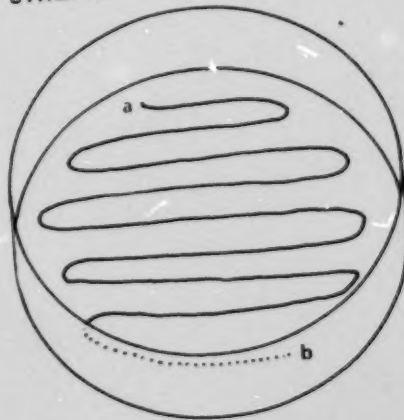
Obtain a sterile test tube

2. Add 1/3 tube of the sand sample to 1/3 tube of sterile sea water, plug the tube, and agitate thoroughly.
3. Permit the sand to settle in the tube, then decant (pour off) several milliliters of the liquid into a sterile tube for your use.
4. Streak three of the four petri dishes with the seawater sample by following these steps:
 - a. Light the burner.
 - b. Flame (pass the loop slowly through the blue portion of the flame) the inoculation loop.

- c. Remove the stopper from the sample bottle.
- d. Flame the mouth of the bottle.
- e. Slowly insert the wire loop or a sterile Q-tip and withdraw a loopful of the sample. Be careful not to touch the sides of the bottle. Flame the bottle mouth and replace the stopper.
- f. Use the technique shown below to streak the plate, being careful not to break the surface of the agar medium. Again, one side of the petri dish lid should be raised only as far as needed to allow you to streak the agar.

Begin at position "a" with the inoculating loop and lightly draw the loop across the agar surface in the illustrated pattern, being careful not to break the surface of the agar. On finishing at position "b" the plate should be closed immediately and the inoculation loop flamed.

STREAKING A PLATE



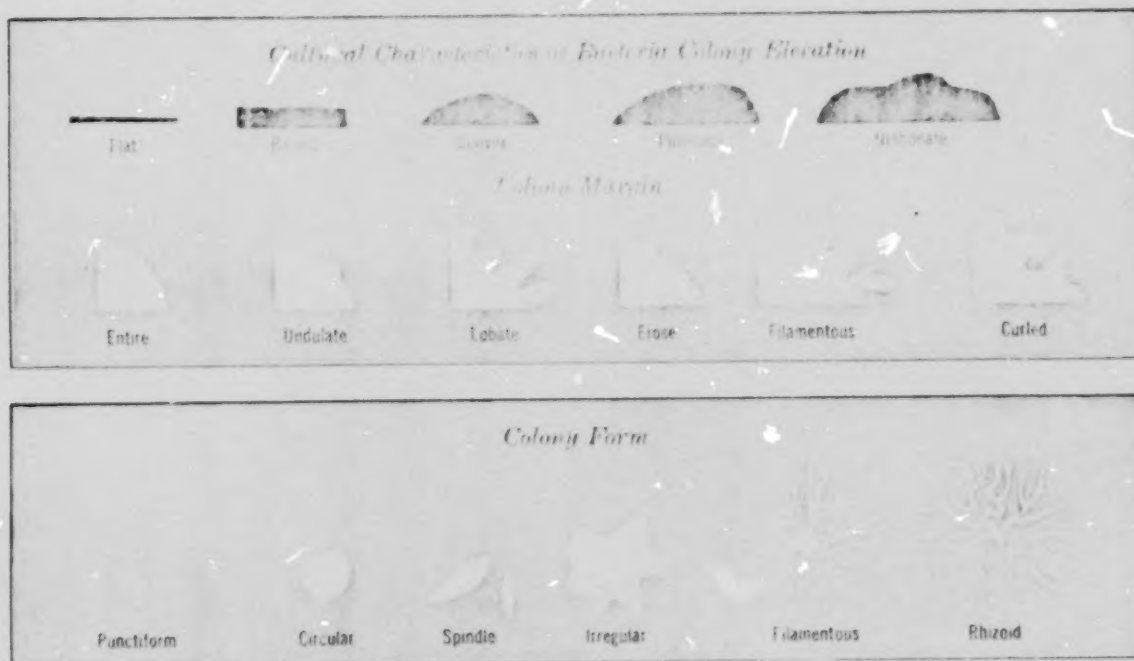
The inoculation loop should be passed through the blue portion of a flame before and after each use.

The mouth of a test tube is to be flamed before and after each

opening of the tube and the tube held at a downward angle when open to prevent contamination falling into the tube from air currents.

- g. The fourth plate is to be used as your control and should not be opened.
5. The dishes of inoculated agar plates are to be kept in a warm humid atmosphere for the next 4 days, preferably in an incubator with a dish of water to provide humidity.
6. The following observations are to be made each day and recorded on the chart provided:
 - a. number of colonies present
 - b. color, shape, and size of each colony
 - c. growth pattern for each colony

Use the following diagrams to help you complete your chart.



At the end of four days,

7. Make a smear of each type of growth on each plate.
 - a. Place a drop of sterile seawater on a clean slide.
 - b. Flame the inoculating loop.
 - c. Pick off a small amount of a colony with the loop and mix it into the drop of water on the slide. Allow this smear to dry.
 - d. Pass the smear (colony side up) through a flame three or four times to fix the bacteria to the slide.
 - e. Let the slide cool to room temperature.
 - f. Gently flood the smear with 2 or 3 drops of crystal violet.
 - g. Allow the stain to remain on the slide for 30 seconds, then pour off the excess.
 - h. Rinse the slide in a beaker of distilled water by immersing gently.
 - i. Remove the water left on the slide by blotting gently with a paper towel. DO NOT RUB.
 - j. Repeat this procedure for as many different kinds of colonies as may be growing on the agar medium. (Remember, cover the petri dish immediately after removing a piece of the bacterial growth).
8. The slides are now ready for observation with the microscope.
 - a. Place a drop of immersion oil on the stained slide and carefully focus under the oil immersion lens. If an oil immersion lens is not available, use the highest power on your microscope.
 - b. Make a rough sketch of each type of bacterial cell you observe.

- c. Repeat this procedure for each prepared slide that your group has done. Identify each organism according to the media upon which it was grown.
- d. Record your results on the data forms.

Analysis and Interpretation:

1. Which type of medium had the most colonies?
2. Which type of medium had the most different kinds of colonies?
3. Why do the three media used contain different things?
4. The fourth plate of each group served as a control. What was done to the other three plates that was not done to the control?
5. Did your control plates have any colony growth? If yes, which one (s)?
6. Groups that have performed this experiment in other classes have occasionally observed colony growth on the control plates. What might be the source of the microorganisms observed in the control plates?
7. Did any of your plates show colony growth in areas outside of the streaked path pattern?
8. What might account for colonies that grew in a location other than along the streaked path?
9. At what point (s) in the procedure is contamination by microorganisms from other sources most likely to occur?
10. Were the microorganisms present originally in the sand or in the sea water? Explain your answer.
11. What are the roles of these organisms in the food chains of the ocean?
12. Which of the roles played by these microorganisms might help explain why they are so numerous in the sand?
13. Which role is probably most critical in maintaining the life of the seas?

Character Culture		Elevation					Margin													
		Flat	Raised	Convex	Pulvinate	Umbonate	Entire	Undulate	Lobate	Erose										
Bacterial Medium	No 1																			
	No 2																			
	No 3																			
Yeast Medium	No 1																			
	No 2																			
	No 3																			
Mold Medium	No 1																			
	No 2																			
	No 3																			
Agar Medium	No 1																			
	No 2																			
	No 3																			
Luminescent Medium	No 1																			
	No 2																			
	No 3																			

Data Chart

Character Culture		Elevation					Margin					Form					Size			
		Flat	Raised	Convex	Pulvinate	Umbonate	Entire	Undulate	Lobate	Erose	Case 1	Flaccid	Plumbeous	Irregular	Spindle	Flaccid	Wet 3 d	Proport	Under 4.5 mm	Over 4.5 mm
Bacterial Medium	No. 1																			
	No. 2																			
	No. 3																			
Yeast Medium	No. 1																			
	No. 2																			
	No. 3																			
Mold Medium	No. 1																			
	No. 2																			
	No. 3																			
Agar Medium	No. 1																			
	No. 2																			
	No. 3																			
Luminescent Medium	No. 1																			
	No. 2																			
	No. 3																			

Data Chart

TEACHER BACKGROUND: Glowing in the Dark: Bioluminescence

Bioluminescence is an interesting and spectacular phenomena. In this activity your students will have an opportunity to culture bioluminescent bacteria. Luminescent bacteria can be obtained by using the following method. It is important to note that this method is not completely foolproof. Unfortunately, the only way to determine if the method in a particular situation will work is to try it!

To culture the bioluminescent bacteria, half-immersed a fresh marine fish in a pan of sea water. Cover the pan with aluminum foil and incubate at 10-15°C for 2 to 3 days. This procedure is designed to induce maximum bacterial growth in the outer slime covering of the fish. If all has proceeded well, luminous spots should be visible to the dark adapted eye in a darkened room. You may elect to have your students take their scrapings from these spots only. If problems occur in the isolation of the luminescent bacteria, a pure culture of the luminescent bacterium, Photobacterium fisheri, can be obtained from the American Type Culture collection (12301 Parklawn Dr., Rockville, MD 20852). The catalog number is E-7744.

Duplicate the activity pages. One page is recommended per student. Completion of the activity "Microscopic Forms: Marine Bacteriology" should have pointed out any potential problem areas in equipment usage and sterile technique. Avoid any of the pitfalls previously encountered. Again, inventory the glassware and supplies required before you begin. Circulate through the room as your students perform the activity. You may wish to demonstrate the techniques again, although your students should be well acquainted with the procedures if they successfully completed "Microscopic Forms: Marine Bacteriology". Remember to allow time for clean-up upon completion of the activity. Plan to provide a few minutes for a discussion of the results and to provide the answers for the

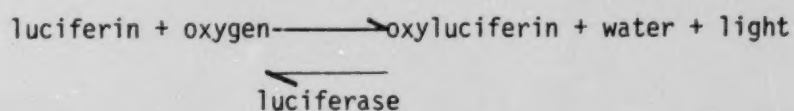
analysis and interpretation questions.

Once again, while it is unlikely that pathogenic organisms have established colonies on the agar plates, it is important to dispose of the bacteria colonies by autoclaving for 20 minutes at 15 pounds pressure (120°C).

KEY

Text questions

1. The term bioluminescence means the production of light by living organisms.
2. Luciferase is a catalyst that speeds the production of light by living organisms. As a catalyst, luciferase is not consumed by the reaction. Without luciferase the reaction proceeds at such a slow rate as to be considered insignificant.
3. We can write the light producing reaction as follows:



4. "Cold light" is light produced at near 100% efficiency; there is no waste heat produced.

Analysis and Interpretation:

1. Answers depend upon the experimental results.
2. Answers depend upon the experimental results.
3. Petri dish number 3 serves as the control.
4. Any colonies that appear in dish number three are due to contamination and poor sterile technique. Possible causes include unclean glassware, failure to flame mouth of test tube, contamination from air while the petri dish was open, etc.
5. The points when contamination by microorganisms from other sources is most likely to occur happen when the petri dish is open during the pouring and streaking procedures or if the dish is opened to observe or count the colonies.

6. The bacteria were most likely in the scrapings since the sea water used was sterile. The bacteria colonies may, however, have come from contamination in the ways mentioned above.
7. The refrigeration of the fish and the incubation at a cool temperature in a dark place seem to indicate that the bacteria prefer lower temperatures.
8. The relationship between fish and bioluminescent bacteria appears to be a symbiotic relationship in which both parties benefit. The fish gains a pattern of luminescence that allows it to be recognized. The bacteria gets a "home" and perhaps a food source in the dead outer slime layer. At any rate, both parties seem to benefit from the relationship.
9. It is important to point out that the benefits subscribed to bioluminescence are based largely on speculation. The actual benefits to a particular organism may not be understood at this particular time. Some of the benefits tentatively assigned include: species recognition, mate recognition and location, a lure for food, a warning signal, illumination, etc. Your students may have theories of their own that merit discussion.
10. The answers will vary. Reward creativity with praise rather than with criticism. One possible experiment might involve altering the lighted pattern on selected members of a species of fish and observing their interaction with non-altered fish of the same species and with similarly altered fish.

KEY WORDS

agar

autoclave

bacteria

bioluminescence

catalyst

colony

enzyme

hypothesis

incubate

inoculated

luciferase

luciferin

luminescence

medium

microorganisms

oxyluciferin

perpetual

petri dish

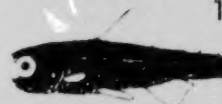
reaction

scalpel

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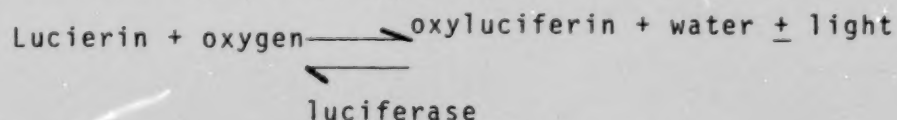
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GLOWING IN THE DARK: Bioluminescence



The cold depths of the sea are without sunlight. Life goes on there in perpetual darkness. Or is it totally dark? Many of the plants and animals cope with this lack of sunlight by producing light of their own. This feeble light is a poor substitute for sunlight but, it does serve to light some of the inhabitants of the seas. Biological luminescence or bioluminescence, the production of light by living organisms, is common in marine plants and animals. The surface of the sea often puts on fiery displays as microorganisms at the surface produce light. The depths are lighted by microorganisms and fish.

What causes this glow? Hundreds of years ago people hypothesized that the ocean absorbed the light of the sun by day and emitted it again at night. Today we know that the light production by living creatures is due to a series of complex chemical reactions. Within the light producing organisms a chemical called "luciferin" (from the Latin for "light bearer") combines with oxygen to yield oxyluciferin and water. In the process light energy is released. It is this light energy that we see. This reaction cannot occur without the presence of an enzyme, luciferase. This enzyme acts as a catalyst; it speeds the reaction but is not consumed by the reaction. We might write the reaction in this manner:



The arrows show that the reaction can occur in either direction. The reaction occurs in the presence of luciferase.

1. What is meant by the term bioluminescence?

2. How does luciferase affect the production of light by living organisms?

The number of organisms in the sea that exhibit bioluminescence is great. Bacteria, fungi, radiolarians, dinoflagellates, sponges, jellyfish, marine worms, squids, crustaceans, clams, snails and fish all have bioluminescent members. Interestingly enough, some of the bioluminescent fish actually have light producing bacteria colonies which live on their surface. It is these bacteria that produce the light. The light patterns always occur in the same place on the same kind of fish. How can this be? The bacteria cannot be inherited in the normal sense of the word since they are a separate organism. Perhaps the developing fish is "inoculated" by the bacteria. An explanation of the regular patterns of light producing colonies awaits further experimentation.

3. How might we write the light producing reaction?

Light production that we are familiar with produces heat. Anyone who has touched a glowing light bulb can witness the heat production. The heat produced is a waste product; we don't want the heat, we want the light. Bioluminescence is a cold light. The reactions are about 100% efficient in light production. All of the energy changed produces light, none produces heat. One molecule of luciferin consumed or burned gives one unit of light. Research into the chemistry of bioluminescence may give us some techniques for improving our own light producing capabilities. Our present lighting is about 50% efficient. Perhaps we can take a lesson from Mother Nature!

4. What do we mean by "cold light"?

In this activity you will have a chance to observe bioluminescence in marine bacteria. The bacteria are obtained from the outer slime covering of a marine fish. The fish has been kept refrigerated for two days. In this exercise, you will need to follow the same sterile technique you used in the activity "Microscopic Forms: Marine Bacteriology".

Materials:

sterile scalpel
sterile petri dishes
sterile test tubes
inoculating loop or "Q-Tip"
Sterile Stopper
Marine Luminescent Bacterial Medium
20 grams peptone
10 grams glycerine
15 grams agar
1 liter sterile sea water

To prepare the medium, bring the water to a simmer. Add the agar and other ingredients and stir until they dissolve. Pour the medium into test tubes and autoclave at 15 lbs of pressure or 120°C for 20 minutes.

Procedure:

1. Prepare 3 petri dishes of medium. Use one dish as a control plate.
2. Scrape a layer of surface slime from the side of the fish, using a sterile scalpel or similar instrument.
3. Place the scrapings in a sterile test tube containing 10 ml. of sterile sea water. Stopper the test tube.

4. Agitate the test tube to mix thoroughly.
5. Use the inoculating loop or "Q-Tip" to streak two petri dishes with the solution. Label these dishes (1) and (2). Label the third dish (3).
6. Incubate all three petri dishes in a cool dark place (not the refrigerator) and observe daily in a dark room. (Allow several minutes for your eyes to become dark adapted).

Observe and record daily:

number of colonies

size of colonies

form of colonies

time of appearance of each colony

amount of luminescence per colony (high, medium, low)

amount of luminescence in test tube before and after shaking
(high, medium, low)

7. When luminescent colonies of bacteria are found, use the inoculating loop to scrape the colony from the surface of the agar.
8. Transfer the bacteria to a sterile test tube containing 5 ml. of sterile sea water and observe in the dark. (Allow several minutes for your eyes to become dark adapted).
9. Shake the tube and repeat observations.

Analysis and Interpretation:

1. Which petri dish had the most colonies?
2. Which dish had the most luminescent colonies?
3. What was the role of petri dish number 3?
4. How can you account for any colonies in dish number three?
5. At what point (s) in the procedure is contamination most likely?

6. Were the bacteria originally present in the sea water or in the fish scrapings? Explain your answer.
7. What conclusion does the refrigeration of the fish and the manner of incubation of the petri dishes lead you to make about the temperature preferences of these bacteria?
8. In the relationship between the fish and the bacteria, who benefits and how?
9. While it is difficult to see the benefit of bioluminescence to the bacteria, benefits of bioluminescence for other organisms may be more obvious. How may deep sea fish benefit from the ability to produce light?
10. Since different deep sea fish have different patterns of illumination it is thought that these patterns may help fish identify their own species. Design an experiment that might help prove or disprove the hypothesis that light patterns are used for species recognition. Be sure to include the materials you will need as well as the procedure you will follow.

TEACHER BACKGROUND - Analysis of Water for Bacterial Pollution

Since time immemorial, cities located along lakes, rivers, or the ocean have disposed of their sewage and industrial wastes by dumping them into these bodies of water. We are no different in this respect from our ancestors. Today the wastes may be pumped directly on to the beach, discharged into shallow waters just offshore, or discharged into deeper waters (50 - 200 feet) a few miles offshore. Treatment of the wastes range from none to chlorination, bacterial decay, settling and oxidation of organic materials. Waters in general, and the ocean in particular, can handle a reasonable burden of wastes. Waves, tides, and currents mix the wastes and dilute their toxicity. Unfortunately, we are now seeing evidence that these bodies of water including the ocean are unable to keep pace with waste overloading. A "super-sewer" outfall near Los Angeles handles nearly a billion gallons of sewage per day. Concentric rings of decreasing heavy metal concentrations and destruction of flora and fauna emanate from the outfall. Sewage threatens the beaches off of New York. The problem is real and it is immediate. This activity provides your students with the opportunity to duplicate a procedure used to determine the presence of sewage pollution. They may use these techniques to monitor local waters. The activity also provides material relating to man's role in the ocean ecosystem.

Duplicate the activity pages. One set is recommended per student. Familiarize yourself with the operation of the Millipore apparatus. The Sterifil apparatus is durable and relatively inexpensive. It can be used for a number of water and air quality experiments. It is not necessary for each group to have a sterifil apparatus. They can be shared and the starting times can be staggered. While four sterifil filters per class of 30 is convenient, a class of 30 can do this activity with one Sterifil filter by combining this activity with "Microscopic Forms: Marine Bacteriology" or "Glowing in the Dark: Bioluminescence". Groups of four

or five are practical for this experiment. A brief demonstration of the Sterifil apparatus and the pipettes before your class begins the activity may help facilitate the smooth performance of the technique. Remind your students of the proper techniques for handling bacteria. Plan to devote some time to a discussion of the results and to provide answers to the questions included in the activity. Additional specific tips are found below.

RESTERILIZATION OF PETRI DISHES:

The petri dishes to be used are made of transparent plastic, with close-fitting covers that help keep the media from drying out. They are sterile as supplied and cannot be boiled without injuring the plastic. However, they can be resterilized by a special soaking technique described below:

1. Using forceps, carefully remove the petri dish covers and then put the covers and dishes (with cultures) into a large beaker or pan containing liquid household bleach (straight from the bottle).
2. After 10 minutes, remove the petri dishes using tongs or a rubber glove and rinse them well under running water. The wet pads and filters should be put into a plastic bag and discarded.
3. Immerse the petri dishes and covers in a solution of 70 percent alcohol for 10 minutes (you can use ordinary rubbing alcohol).
4. After 10 minutes, remove the petri dishes and stack them on a clean surface. Then assemble the dishes and covers. They are now ready for use.

CAUTIONS FOR USE OF HAWG FILTERS:

Millipore filters will "flash burn" if accidentally ignited. Let the forceps cool for a few seconds after flaming but before you use them to pick up the filter. This pause will prevent the filter from being scorched.

If there is any residual moisture on the filter base, it will wet the filter slightly, but this does no harm.

MF-ENDO MEDIUM:

This medium will STAIN skin, clothing, etc., if it comes in contact with same.

COUNTING THE COLONIES:

The following procedure may be used to facilitate coliform colony counting.

Place the dried filters between 2" x 3" slides (hinged with tape) and examine for coliform colonies under 5-10x stereomicroscope magnification. The illumination should be nearly perpendicular to the filter from above. Count all coliform (green sheen) colonies on the filter having the maximum number not exceeding 200. Preferable, the number of colonies should be between 20 and 80. Express results in terms of coliforms per 100 ml of sample water.

$$\text{Number Coliforms/100 ml} = \frac{\text{Number Coliform Colonies observed} \times 100}{\text{Volume of Original Sample Filtered (in-ml)}}$$

While it is unlikely that pathogenic bacteria have established themselves on the petri dishes, it is possible. Destroy the bacteria colonies by incineration of the filter and pads. Sterilize the petri dishes as detailed above. It is important to destroy the colonies to demonstrate to your students the proper technique and regard for potential pathogenic infection.

KEY**Text questions**

1. Decomposers are organisms that break down organic material thereby releasing nutrients necessary for the growth of plants. The decomposers are the recyclers of the ecosystem.
2. Many factors influence the number and kinds of bacteria present in natural waters. These include: the source of the water, its temperature, the types and concentrations of dissolved minerals present, and, the types and concentrations of dissolved organic materials, (sewage, etc).

3. Large numbers of bacteria can affect normally balanced water ecosystems by reducing the oxygen available for fish and other aquatic life. The reduction in oxygen levels can cause the death of these other aquatic forms.
4. Coliform bacteria are normally found living in the digestive tract of man and other mammals.
5. People are interested in monitoring the number of coliform bacteria in drinking water because the coliform bacteria are a good indicator of pollution since fecal coliforms do not normally reproduce outside of the digestive tract. The presence of large numbers of coliform bacteria shows the almost certain presence of other bacteria that are harmful to man.
6. Water quality experts sample water for coliform bacteria rather than for pathogenic organisms like Salmonella typhosa because coliforms are always present in sewage and are difficult to kill. If coliform bacteria are not present in the test sample, we can be reasonably sure that no other bacteria due to sewage pollution are there either.
7. A "membrane filter" is a filter that contains billions of microscopically uniform holes per square centimeter.
8. The following is the proper sequence for the steps of the Millipore Membrane Method:
 - 5 a. the number of coliform bacteria are counted.
 - 1 b. the water sample is taken in a sterile container
 - 3 c. the filter is placed in special petri dish in which a pad has been soaked with a prepared culture medium.
 - 2 d. the water sample is filtered using the Millipore apparatus.
 - 4 e. the petri dishes are incubated while the bacteria grow
9. The green sheen color distinguishes coliform bacteria colonies from other bacteria colonies growing on the MF-ENDO medium. The other colonies are red.

10. The total number of coliform bacteria colonies present in a petri dish is determined by counting the number of green sheen colonies on the petri dish. This question reemphasizes the fact that the necessary information is obtained by a simple counting of the green sheen colonies.

ANALYSIS AND INTERPRETATION:

1. Answers depend upon experimental results.
2. Answers depend upon experimental results. This question is designed to give your students a chance to see what their results mean in terms of water quality standards.
3. Answers depend upon experimental results.
4. Sterile water was used for dilution so that no additional coliform bacteria would be introduced into the sample through the dilution process.
5. Dechlorinated water was used for dilution so that the bacteria would not be killed by the chlorine. Chlorine is added to the water to kill bacteria.
6. Averaging results from groups using the same water samples tends to give more reliable results: the very high and the very low counts tend to balance each other. This may be a good point for a discussion of the merits of pooling data.
7. Answer depends upon the experimental results but, one would not expect the individual results to be exactly the same as the class average.
8. There are many possible explanations for differences between individual results and the class average. These include: the bacteria may not have been uniformly distributed in the sample, the sample size aliquots were not of identical size, the pad may have become contaminated during the process, the filter paper may not have made good contact with the medium soaked pad, the filter may have become contaminated during handling, the glassware may have contained coliforms, the dilution water may have contained coliforms

or chlorine, etc. Your students will suggest other sources of error. Many of the sources suggested are controllable. Solicit ideas regarding how to control these potential sources of error and how likely each source is to occur.

9. The absence of coliform bacteria in a particular sample does not guarantee that no coliform bacteria were originally present. It is possible that the .5ml sample did not contain coliforms while the remainder of the solution did. For this reason several samples are taken to increase the faith one can place in the results. We cannot say for certain that no coliforms are present in a sample, but we can say it is unlikely that any are present.
10. Your students will have many suggestions. Coliform numbers can be reduced by reducing the sewage outflows or by increasing the treatment of the effluent waters to reduce bacteria levels. This question may serve as a springboard for a discussion of the ways in which your community deals with waste waters and sewage and how your community's actions contribute to the entire picture.

KEY WORDS

aldehydes

aliquot

ampoule

artesian wells

average

bacteria

basic fushin

coliform bacteria

colony

culture medium

dechlorinated water

decomposers

digestive tract

dilution
dysentery
epidemics
feces
festering cesspools
forceps
green sheen
lactose
medium
membrane filter
MF-ENDO medium
Millipore Membrane Method
monitoring
nutrients
organic
parasitic
pipette
pollution
sewage
sodium sulphite
Sterifil Filtration Apparatus
total coliform analysis
typhoid fever



ANALYSIS OF WATER FOR BACTERIAL POLLUTION

Bacteria, as part of the food web, play an important role as the "decomposers". In such a role they break down organic material, releasing nutrients necessary for the growth of plants. Parasitic bacteria, also found in waters, serve to remove weakened organisms. In cases of overcrowding of a particular species, parasitic bacteria can cause epidemics which tend to keep these populations in check.

1. What are decomposers?

To a large extent the number and kind of bacteria present depend upon the source of the water, its temperature, and the types and concentrations of dissolved minerals present. Artesian wells and springs have a lower bacteria count than shallow ponds and streams. Sewage and waters heavily polluted with organic materials contain millions of bacteria per milliliter. If the sewage enters rivers, bays, or other natural waters, these millions of bacteria are introduced into the waters also. There they continue to grow on the rich nutrient medium provided by the sewage.

2. What factors help determine the number and kinds of bacteria present in natural waters?

Millions of dollars are being spent in programs to clean up the rivers, lakes and smaller streams in the United States. Aside from the fact that sewage pollution is a disease hazard, it is of broader ecological importance in that it may bring abnormally large numbers of bacteria to an otherwise normally balanced water ecosystem. Some bacteria use significant amounts of oxygen in their life processes. These bacteria remove oxygen from the water. The oxygen, then, becomes unavailable for fish and other aquatic life. Periodic fish kills can often be traced to this sudden oxygen depletion. Many streams in this country that were once alive with fish are now nothing but festering cesspools.

3. How can large numbers of bacteria affect normally balanced water ecosystems?

The established method of detecting sewage pollution of water involves a growth test for the presence of coliform bacteria. Coliform bacteria are normally found living in the digestive tract of man and other mammals. Coliform bacteria are expended by billions in feces (solid waste matter) and find their way into the water supply with sewage. Though coliforms are not harmful themselves, their presence is a good indicator of sewage pollution since fecal coliforms do not normally reproduce outside of the digestive tract. In a coliform growth test, bacteria from a water sample are grown under controlled conditions. THE PRESENCE OF LARGE NUMBERS OF COLIFORM BACTERIA SHOWS THE ALMOST CERTAIN PRESENCE OF OTHER BACTERIA THAT ARE HARMFUL TO MAN.

4. Where are coliform bacteria usually found?

5. Why are people interested in monitoring (keeping track of) the number of coliform bacteria in drinking waters?

In densely populated areas, water pollution by sewage is an ever present hazard. Several serious diseases can be traced to polluted drinking water. Among them, typhoid fever and a group of intestinal disorders generally lumped under the name of "dysentery". The actual disease causing organisms, such as Salmonella typhosa, may be extremely hard to detect. Instead of testing for these health bacteria directly, authorities routinely check for the presence of coliform bacteria, which we have already mentioned as an indicator of water pollution. Coliforms, always present in sewage, are much harder to kill in treatment plants than the actual disease producers. If coliform bacteria are not present in the test sample of waste water, we can be reasonably sure that no other bacteria due to sewage pollution are there either.

6. If water quality experts are interested in the presence of disease organisms why don't they sample water for organisms like Salmonella typhosa instead of for coliform bacteria?

Sewage laden rivers and streams flow into coastal waters. Analysis of water for bacterial pollution is an important step in monitoring the quality of waters along our coast lines. In this activity you will have an opportunity to test various water samples for coliform bacteria as an indicator of sewage pollution.

To determine the total coliform bacteria concentration in a water sample, you will use the Millipore Membrane Method. The Millipore Membrane Method for total coliform analysis involves filtering the water sample through a "membrane filter" (a filter that contains billions of microscopically uniform holes per square centimeter). The filter is then placed in a special petri dish in which a pad has been soaked in a prepared culture medium. A culture medium is the "soil" for growing microorganisms and contains the food nutrients required for growth. Each coliform bacteria produces an easily recognizable colony. Recall that THE NUMBER OF COLIFORM COLONIES IS EQUAL TO THE NUMBER OF COLIFORM BACTERIA PRESENT IN THE ORIGINAL WATER SAMPLE.

7. What is a "membrane filter"?
8. Organize the following steps of the Millipore Membrane Method in their proper sequence. Write the number of the step in the blank space.
 - ___ a. the number of coliform bacteria are counted.
 - ___ b. the water sample is taken in a sterile container
 - ___ c. the filter is placed in special petri dish in which a pad has been soaked with a prepared culture medium.
 - ___ d. the water sample is filtered using the Millipore apparatus.
 - ___ e. the petri dishes are incubated while the bacteria grow

MF-ENDO MEDIUM is used to verify the presence of coliform bacteria, and how it does so is a perfect example of microbiological detective work. Years ago, researchers learned that coliform bacteria have a unique ability to break down a complex sugar called lactose, forming a definite sequence of simpler

substances. Some of these, showing up about 36 hour after the process starts, are called aldehydes.

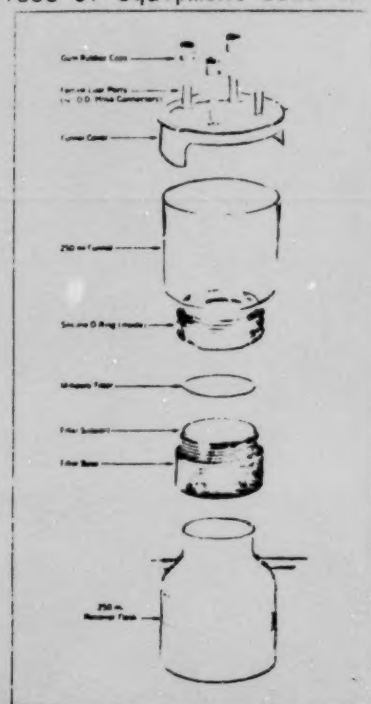
The MF-ENDO MEDIUM contains lactose and other nutrients, and also a stain -- basic fuchsin -- which is normally deep red but has been made pale pink by the addition of sodium sulfite. The first action of bacteria...in fact, of the air itself...is to partly reverse the effect of the sulfite, making the whole surface of the medium red. Most colonies growing there also become red, but with nothing to distinguish one species from another until the aldehydes are formed. When this happens, the unchanged fuchsin-sulfite complex (plenty of it is still around) attaches itself to the aldehyde molecules and forms a shiny green coating. Because no microorganisms make aldehydes out of lactose except members of the coliform family, "green sheen" colonies are coliform bacteria, and the sample is proved guilty of pollution by sewage. ALL BACTERIAL COLONIES THAT HAVE A GREEN SHEEN ARE COUNTED AS COLIFORMS.

9. What distinguishes coliform bacteria colonies from other bacteria colonies growing on the MF-ENDO MEDIUM?
10. How would you determine the total number of coliform bacteria colonies present in your petri dish?

The STERIFIL FILTRATION APPARATUS is the central piece of equipment used in these experiments. Its component parts are shown in Figure 1.

To avoid adding additional coliform bacteria to the water sample, sterile technique is practiced. Before each experiment, the funnel and filter base must be sterilized. The receiver flask does not require sterilization.

Figure 1



Materials:

water samples (s)

Millipore filtration unit with hand pump

Petri dishes, 47 mm

Millipore filters with absorbent pads, HAWG 47 mm, 0.45, sterile

Forceps, blunt

70% Alcohol for sterilizing

Media - Ampule containing 2 ml MF-ENDO MEDIUM (pink)

Ampule breaker

Sterile pipette, 1 ml in 1/10

Sterile pipette, 50 ml or 100 ml graduated cylinder

Sterile dechlorinated water

Incubator

Binocular scope, hand lens or Colony counter.

Boiling water

Tongs

Procedure:

1. Collect a sample of salt water at the site specified by your teacher using a sterilized container that can be capped shut during transportation.
2. Prepare the following:
 - a. Sterifil apparatus, with HAWG filter.
 - (1) Sterilize the funnel and the filter base by immersing both in rapidly boiling water for 3 minutes. After boiling, lift the funnel and filter base out of the water with tongs and place them on a clean sheet of wrapping paper. The funnel should rest upside-down on its larger rim, while the filter base rests with the filter support area up. Do not wipe these

The VACUUM SYSTEM, used to operate the filtration unit, consists of a plastic syringe, a length of rubber tubing, and a two--way valve. One end of the tubing carries a small nylon adapter. Slip the other end tightly over the side vent of the valve, and attach the valve to the syringe (Figure 2). Insert the nylon adapter into one side arm of the Sterifil receiver flask (figure 3), and close the other side arm with a gum rubber cap.

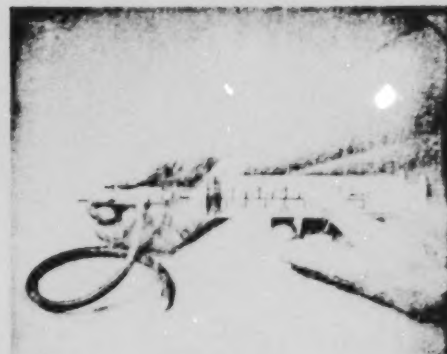


Figure 2

When the syringe plunger is worked (figure 4), air will be drawn out of the receiver flask and vented through the valve outlet. This will quickly create sufficient vacuum inside the receiver flask to start and maintain the filtering process, perhaps with an occasional "boost" from the syringe.



Figure 3

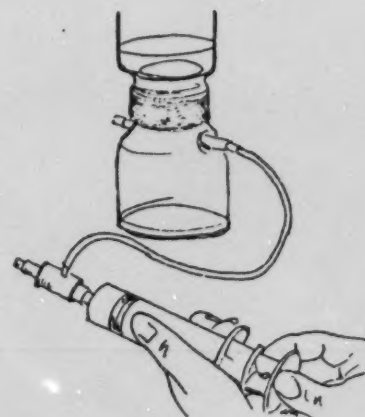


Figure 4

units, and do not touch the inside of the funnel or the top of the filter support with your fingers. Allow the pieces to drain for a moment or two, then press down the filter base firmly over the top of the receiver flask. The O-ring may tend to fall out of its groove during boiling. If this happens, place the O-ring back in the groove using sterile forceps. Then screw the blue filter base into the funnel until the O-ring seats properly.

- (2) DO NOT TOUCH THE HAWG FILTER WITH YOUR HANDS. To install the HAWG filter:

First sterilize the forceps by dipping the tips in alcohol and while still coated with a thin layer of alcohol, passing it quickly through the flame of the alcohol burner. LET THE FORCEPS COOL BRIEFLY, then use it to lift a single filter out of the box.

NOTE: The blue wax paper discs in the envelope are merely part of the packaging and should be discarded.

Put the cover back on the top of the filter base, centering it accurately. (Figure 6).



Figure 6

Complete the assembly by screwing the funnel down over the filter base (figure 7). BE CAREFUL not to use too much force or the filter itself might get torn and be rendered useless.

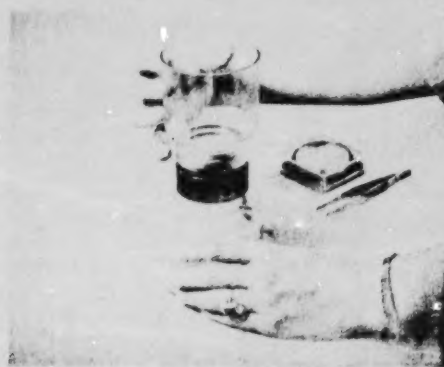


Figure 7

b. One petri dish and pad, with MF-ENDO medium (pink).

- (1) To open a petri dish, insert a forceps balde between the sections and pry with a twisting motion (Figure 8). Be careful not to touch the inside surface of either section.

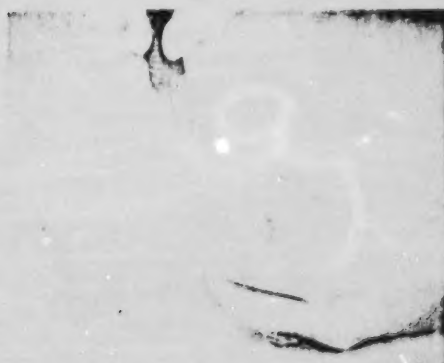


Figure 8

Using flamed forceps, a 47 millimeter absorbent pad can now be placed in the bottom section (Figure 9) to receive the selected culture medium. (The white absorbent pads are in the box with the HAWG filters).

NOTE: THE FACE WITH RAISED LETTERING SHOULD BE TREATED AS THE BOTTOM, KEEPING THE CLEAR FACE AS THE TOP FOR EASIER OBSERVATION OF GROWTH.



Figure 9

- (2) Obtain a sealed glass ampoule (a small, sealed vial) of MF-ENDO MEDIUM.

Sterilize the neck of the ampoule by holding as is shown in Figure 10, and quickly passing it through the flame while turning it so that all sides of the extended neck are sterilized.



Figure 10

Next, insert the ampoule into the ampoule breaker, and holding the bottom of the ampoule, squeeze the sides of the breaker together to snap the neck (Figure 11). Not

too much force is needed.



Figure 11

Pour the contents of the ampoule evenly over the absorbent pad in the petri dish, making sure that the entire pad is saturated (Figure 12).

NOTE: If the medium does not flow evenly due to the small opening, shake gently to release the medium.



Figure 12

NOTE: If (as sometimes happens) a small shred of glass from the broken ampoule gets into the pad, simply lift it off with flamed forceps, then replace the petri dish cover loosely until sample filtration has been completed.

YOU ARE NOW READY TO FILTER YOUR WATER SAMPLE.

3. Using the 50 ml pipette or a 100 ml graduated cylinder, place 50 ml of sterile dechlorinated water into the Sterifil funnel.
4. Pipette a 0.5 ml sample of the sample water into the Sterifil funnel, and swirl the funnel to mix the sample with the sterile dilution water.
5. Using the vacuum apparatus, filter the diluted water sample.
6. Using the 50 ml pipette or a 100 ml graduated cylinder, place another 50 ml of sterile dechlorinated water into the funnel and filter through. This is to prevent the bacteria from clumping or becoming encrusted in salt, since the sample is taken from salt water.
7. Using the vacuum apparatus, filter the second 50 ml dilution.
8. Release the vacuum in the system by removing the vacuum pump tubing from the side-arm of the Sterifil receiver flask. Unscrew the funnel, and using flame-sterilized forceps, lift the filter from the Sterifil base and place it (gridded side up) on the saturated absorbent pad in the petri dish. Carefully line up the filter with one edge of the petri dish and then set it down with a slight rolling motion (Figure 13), so that it is evenly centered.



Figure 13

9. Replace the cover and invert (turn over) the petri dish. LABEL the dish with your name.
10. Allow the culture to incubate for 48 hours at normal room temperature,

or 24 hours at 37°C if you have an incubator.

11. After incubation, remove the test filter with flamed forceps and allow it to dry on a clean blotter for 1/2 hour.
12. With a hand magnifier, or colony counter, scan the surface of the filter for colonies having a shiny, greenish surface. Count the total number of these "green sheen" colonies appearing on the filter. This is the number of coliform bacteria present in the 1/2 ml sample of untreated water.

RECORD THIS NUMBER ON YOUR DATA SHEET. Multiply this by 2 to find the number in one ml of the same water.

RECORD THE NUMBER OF COLIFORM BACTERIA per ml on your data sheet.

NOTE: If the number of coliform bacteria in your sample is too numerous to count, your water is heavily polluted. In this case, repeat the above procedure using a 1/4 ml sample instead of a 1/2 ml sample. Multiply the count by 4 to determine the number of bacteria per ml.

13. Compare your results with the other teams that used an aliquot (a measured sample) from the same water sample. This can be easily done if each team records its results on the blackboard.

Determine a class average for your sample.

RECORD this average on your data sheet.

14. Disassemble and clean the Sterifil and syringe in warm water and detergent.

NOTE: If the filter base is too tight to be easily removed, screw the funnel part back onto the blue filter base and rock the two parts in opposite directions while pulling apart.

15. Finally, and most important, WASH YOUR HANDS.

Analysis and Interpretation:

1. Using your data, determine how many coliform colonies there were in a 100 ml sample of your water. Coliform test results are usually expressed as #/100 ml.

RECORD this answer on your data sheet.

2. Coliform population limits have been set by federal and state health services. These limits vary with the designated use of water supply. The U.S. Public Health Service has set a national standard for drinking water of no more than 1 coliform colony per 100 mls. While standards now vary with area, it is generally felt that the following criteria are useful for fecal coliform populations (TABLE 1).

TABLE 1 - WATER QUALITY CRITERIA WITH RESPECT TO FECAL COLIFORM POPULATION

<u>Kind of Water</u>	<u>Recommended Numbers of Fecal Coliforms</u>
1. Water designated for Primary Contact Recreation.	1. Should not exceed an average of 200/100 ml.
2. Water other than for Primary Contact Recreation.	2. Should not exceed a mean of 1000/100 ml.
3. General Recreation Surface Water.	3. Average not to exceed 2000/100 ml.

Primary Contact Recreational Activities are defined as those activities in which there is a prolonged and intimate contact with the water involving considerable risk of ingesting water quantities sufficient to pose a significant health hazard.

The Food and Drug Administration recommends that the surface waters above shell fish beds shall not have fecal coliform counts above 70/100 ml.

How does your number /100 ml compare with the U.S. Public Health Service standards for drinking water?

3. Using TABLE 1, for what kind of activity would this water be suitable?
4. Why was sterile water used to dilute the sample in steps 3 and 6?
5. Why was the water used for dilution dechlorinated?
6. In step 13, what is the reason for averaging the class results?
7. How does your determination compare with the class average?
8. What are four reasons that your results might differ from the class average?
9. If your results showed no coliform bacteria present, can you be safe in saying that there were none in your water sample? Explain.
10. What things can be done to reduce the number of coliform bacteria in coastal waters?

Name _____

Total Coliform Analysis

Millipore Membrane Method Data Sheet

1. Date _____.
2. Sample location _____
3. Number of coliform colonies per .5 ml _____
4. Number of coliform colonies per 1.0 ml _____
5. Average number of coliform colonies from same water sample _____.
6. Number of coliform colonies per 100 ml for your sample _____

From Table 1:

This water sample is suitable for: _____

BIOLOGICAL FACTORS:

Plankton - Sea Drifters

TEACHER BACKGROUND - Out of Sight

Plankton are a world unto their own. Phytoplankton, the usually microscopic wandering plants of the sea, are the basis for life in the sea and, perhaps, on land as well. These tiny organisms capture the energy in sunlight and pass it on to all the other members of the marine food webs. Without this food source, the life we know in the sea would not exist. The same phytoplankton produce the majority of the oxygen available to both aquatic and terrestrial animals. The importance of these minute organisms cannot be over estimated. The exercise "Out of Sight" is the first of several exercises dealing with these interesting creatures. A crossword puzzle designed to reinforce the teaching of the new vocabulary is included after the text pages. The puzzle originated with Mrs. Carolee Parmer, a marine consultant for the Florida 4-H Marine Program. A list of reference materials will be found at the end of this teacher background section.

Duplicate the text pages. One set is recommended per student. This activity lends itself to individual completion in class or as a homework assignment. Be aware of the new vocabulary and especially of the familiar vocabulary that is used in a new and specific manner (for example, "producer", "consumer"). The crossword puzzle helps to review the new vocabulary terms. Upon completion of the puzzle, allow time for a discussion of the concepts covered and to provide answers to the questions in the text and in the crossword puzzle.

KEY

1. The primary difference between phytoplankton and zooplankton is that phytoplankton are plants that produce their own food while zooplankton are animals that must obtain their food from other sources. Your students may not recognize this important distinction at this point. They may instead refer to the pictures above in search of differences. This latter approach is acceptable but you need to point out the primary difference during your discussion of this material.

2. This problem may be set up as follows:

$$\begin{array}{rcl} \frac{40 \text{ liters}}{\text{aquarium}} & \times & \frac{4,500,000 \text{ phytoplankton}}{\text{liter}} = 180,000,000 \text{ phytoplankton} \\ & & \text{in the aquarium} \end{array}$$

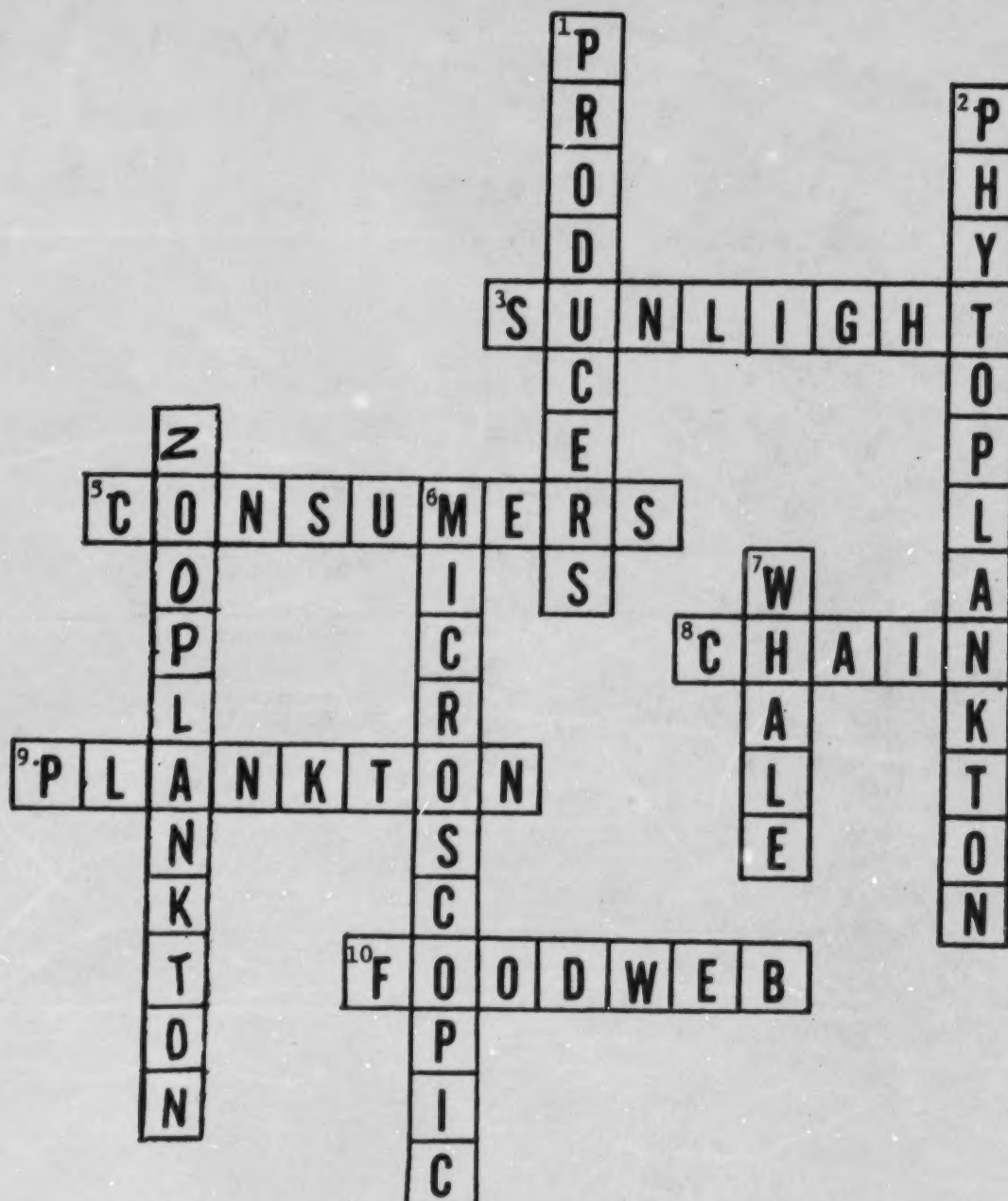
This calculation is designed to show the abundance of planktonic organisms. Unfortunately, a number like 180 million is hard to appreciate. You might try this analogy: If your students started spending money at the rate of one dollar per second, it would take 3 million minutes or 50,000 hours or 2,083 days or 5.7 years of continuous round the clock spending to spend 180,000,000 dollars!

3. Animals that live below the lighted zone depend upon: (1) the constant rain of small detritus that falls from the lighted layers; (2) the occasional large carcass that falls from above; (3) preying on animals that feed in the lighted zone and then swim into the lower depths; and/or (4) trips into the lighted zone to feed.
4. Six molecules of oxygen are released for each sugar molecule produced by the phytoplankton. This question is designed to let you see if your students have a grasp of what the equation for photosynthesis is saying.
5. The answers depend upon the experience of your students. Land based food chains are acceptable including the standard: grass → cow → man. This question is designed to help relate the new concept to familiar situations.
6. Since the small fish is a second order consumer, we would call a medium sized fish that ate the small fish a third order consumer.
7. The answers will depend upon previous experience. Any reasonable answer is acceptable. The level of the consumer added will vary with the animals chosen.
8. The problem may be set up as follows:

$$\begin{array}{ccccccc}
 6.5 \text{ oz} & \times & 24 \text{ cans} & = & 1560 \text{ oz} & \times & 1 \text{ pd.} \\
 \text{can} & & \text{case} & & 16 \text{ oz} & & \text{case} \\
 & & & & & & & \times & 10,000 \text{ pds. of} & = & 97,500 \text{ pds.} \\
 & & & & & & & & \text{phytoplankton} & & \text{phytoplankton} \\
 & & & & & & & & \text{pound of tuna} & &
 \end{array}$$

9. Strictly speaking, to maximize the amount of marine food available to man, we should harvest the producers (phytoplankton) directly. This is not always possible for many reasons both economic (cost of harvesting a diffuse organism) and sociological (people often eat new and strange tasting items). The farther down the food chain we feed, the greater the amount of food available.
10. Man would be affected in many ways by the death of all of the ocean's plankton just as we are diminished by the death of any species. In specific, however, we would find ourselves without most of the food we harvest from the ocean and without oxygen to breathe. Fairly considerable negative impacts!

KEY

Solution to Crossword Puzzle

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OUT OF SIGHT

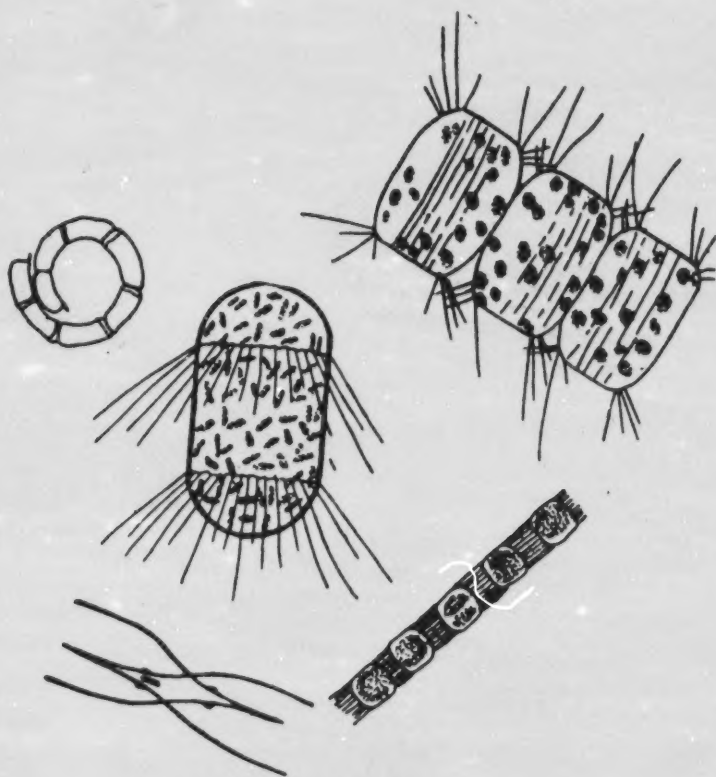
Hold a drop of sea water from the sea. Clear, colorless, and uninteresting. Place that same drop of water under a microscope and a new world appears. Within a single drop we can find a population of minute plants and animals. What are these creatures? How are they important to life in the ocean and to man?



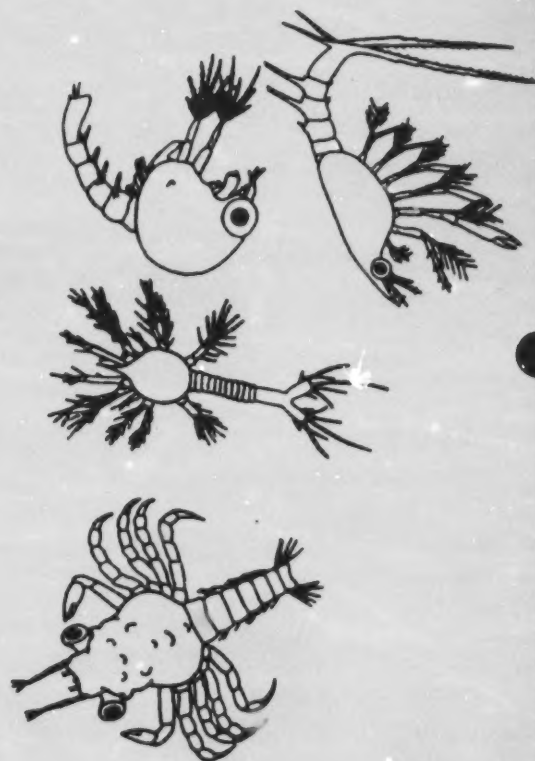
PLANKTON

These tiny plants and animals are members of a group of organisms that we call plankton. "Plankton" comes from a Greek word "planktos" which means wandering. Plankton are wanderers in the sense that they just float along with the water. These organisms have a limited ability to swim, in a real sense they are at the mercy of the tides and currents. Not all plankton are microscopic but for the most part as we discuss plankton we will limit ourselves to those that are microscopic. Be aware, however, that some planktonic animals may be two or three feet across.

Since planktonic plants play a different ecological role than planktonic animals, oceanologists have given the two groups different names. Plant plankton is called phytoplankton ("phyto" is Greek for plant) while animal plankton is called zooplankton ("zoo" is Greek for animal). The term "plankton", then refers to all of the floating plants and animals, both the phytoplankton and the zooplankton.



PHYTOPLANKTON



ZOOPLANKTON

1. What is a major difference between phytoplankton and zooplankton?

Careful studies by biologists at the marine laboratory at Plymouth, England found that the ocean water they were examining contained, at the very least, four and a half million (4,500,000) phytoplankton in each liter of water! Even if we recognize the fact that the seas, like the land, vary in productivity, it is clear that by sheer numbers alone phytoplankton must play an important role in the life of the sea. What exactly is that role?

2. Mr. Science decided it was time to set up an aquarium in his classroom. He went to the ocean beach and filled his forty liter aquarium with clear, colorless sea water planning to add some "sea life" later. Poor Mr. Science! How many sea creatures did he already have in his aquarium? (Assume that his sea water was like that examined in the lab at Plymouth, England). Please show your calculations

Because phytoplankton support most of the herbivores of the sea, phytoplankton may be accurately called the "grass of the sea". As the sea's primary producers, phytoplankton trap and store the energy contained in sunlight. In the process of photosynthesis, the phytoplankton use carbon dioxide (CO_2) and water to produce more organic matter (food) than any other group of plants. Since phytoplankton need sunlight, they are found only near the surface of the ocean where the sunlight can reach them. It is interesting to note that phytoplankton produce oxygen in proportion to the amount of carbon dioxide they use. Some scientists calculate that without this oxygen production, life as we know it on the earth would not be possible. This fact alone should make us very cautious in our treatment of the oceans! Without the food production by phytoplankton there would be no food for the microscopic grazing zooplankton. There would also be no fish since they feed directly or indirectly on the smaller grazers.

3. Phytoplankton are limited in vertical distribution by how far sunlight penetrates seawater. While blue light can penetrate to a depth of over 500 meters, the light that the phytoplankton can use is largely limited to the upper 70 meters of the ocean. Yet, we know that life exists below the 70 meter depth in the oceans. What are two possible sources of food for animals living below the lighted zone?
4. The equation $6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \xrightarrow{\text{(in sunlight)}} \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$ describes photosynthesis. It tells us that through a long process which occurs in the presence of sunlight, six carbon dioxide molecules (CO_2) and six water molecules (H_2O) are combined to give us one molecule of a simple sugar ($\text{C}_6\text{H}_{12}\text{O}_6$) and six molecules of oxygen (O_2). How many oxygen molecules are available to animals including man from the production of each sugar molecule by phytoplankton?

Nearly all of the phytoplankton species are used as food by small invertebrate (no backbone) animals that feed by filtering the water. Zooplankton such as the copepods and euphausiids and crab larvae and attached organisms, such as mussels and clams, feed in this way. These filter feeders are fed upon, in turn, by larger invertebrates and fish. All of these animals either consume directly or indirectly the food that the producers have stored. As a result, we call these animals consumers. We might draw a food chain to help see the relationships:



This simple food chain shows us that the small fish ate the zooplankton that ate the phytoplankton. The arrows show which way the energy and matter stored by the plants are moving.

5. Use your knowledge of plants and animals to draw another food chain with at least three members. Label the producer and the consumers.

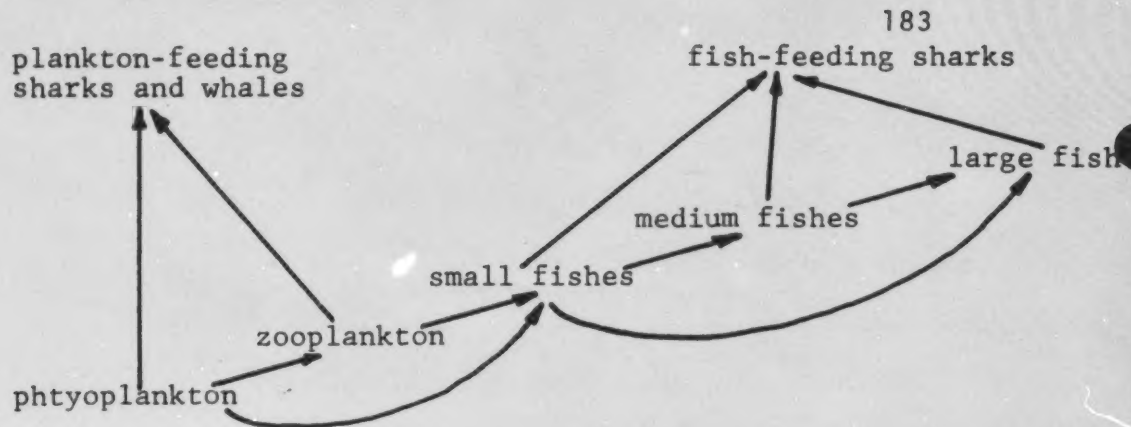
Sometimes it is helpful for us to know whether the consumer we are talking about was the one who ate the producer, or one who ate another consumer. To accomplish this, we call a consumer who eats green plants a first order consumer. A consumer who eats a first order consumer is called a second order consumer and so on. At each energy transfer (for example, a second order consumer eating a first order consumer) about 80 to 90% of the energy is "lost", only 10 to 20% of the energy is available to the higher order consumer. Because of this energy loss food chains are seldom over four or five links long.

6. In the food chain mentioned above, what would we call a medium sized fish that ate the small fish?

"Aha?", I hear you say, "What about the small fish that eats both zooplankton and phytoplankton?" Okay, you've got me. When the small fish eats the phytoplankton it is a first order consumer and when it eats the zooplankton it is a second order consumer. We can draw the food chain like this:



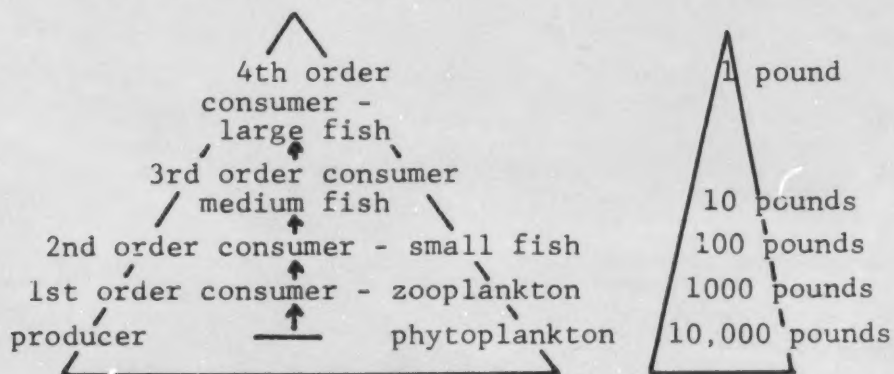
Now our food chain has become a food web. A food web is made of several food chains. We can find many such food chains and food webs, both on land and in the sea. Sometimes they can become very complicated.



We could continue to add members to this web until it became very much more complicated.

7. Add one more member to the food chain shown above. What level consumer is your addition?

Let's look at our food chain again. It is obvious that a plankton feeding shark would have to eat a great deal of plankton to stay alive. Let's isolate one food chain out of our web and see how much phytoplankton it takes to feed a fourth order consumer, a large fish. We have a clue. We've seen that processes like respiration ("breathing") and natural mortality (death) cause the loss of 90 per cent of the energy at each step in the food chain. Let's see how much phytoplankton it would take to produce one pound of our large fish; it takes 10 pounds of medium fish which needed to eat 100 pounds of small fish which needed to eat 1000 pounds of zooplankton which needed to eat 10,000 pounds of phytoplankton!



Wow! To produce one pound of our fourth order consumer fish, we had to start with 10,000 pounds or 5 tons of phytoplankton. Without phytoplankton, we would have no fish to eat.

8. An example of a large, fourth order consumer fish would be a tuna. Tuna comes to our supermarkets usually packed in 6 ½ ounce cans. There are 24 of these cans in a case. How many pounds of phytoplankton were required to produce each case of tuna? (Hint: How many pounds of tuna are there in a case?)

Many people regard the ocean as an unlimited source of food which we have not yet begun to tap. From the above discussion it should be obvious that the total production of marine food animals depends upon the annual rate of production of phytoplankton. We must also consider the fact that marine food for human consumption must be both economical to harvest and edible. The amount of marine food available to humans also depends upon the consumer level of the food organisms we choose.

9. To maximize the amount of marine food available to man, what level consumer should we harvest?

According to some marine biologists, the maximum sustainable yield (the production which can be sustained year after year without the yield decreasing) of ocean fish of the kinds we presently eat, can be doubled from the present harvest of 60 million tons per year. To exceed this yield would require that we harvest directly the organisms that fish feed upon, such as euphausiids, shrimp, and squid. These organisms are more abundant but also more expensive to catch and this approach does not at present seem feasible or economical. Even the present yield is imperiled by overfishing, and by pollution from pesticides,

herbicides, and oil. For example, DDT has a negative effect on photosynthesis of algae at a concentration of just one part in a billion parts of water, and an oil layer reduces the light available for photosynthesis. It is conceivable that over-fishing and pollution could reduce our potential harvest from the sea.

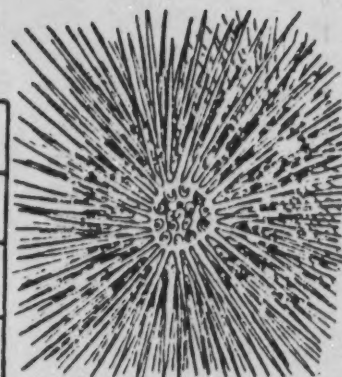
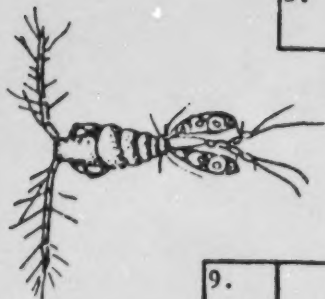
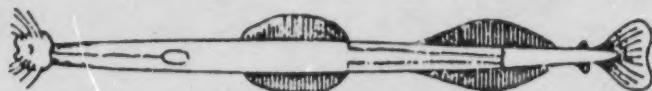
10. What are two ways man would be affected by the death of all of the ocean's phytoplankton?

The importance of phytoplankton to the economy of the ocean and the world cannot be underestimated. The health of these minute organisms has a direct impact on human welfare. Plankton, so seemingly insignificant in reality, are the basis for all fish life in the ocean.

AN "OUT OF SIGHT" PUZZLE

Across

3. What all green plants need so that they can store energy.
5. Animals that feed on other organisms. (1st order ____, for example)
8. Food
9. Organisms that float and drift with the movement of the water.
10. Many food chains make this (two words)



Down

1. Green plants' role in a food chain or food web.
2. Planktonic plants.
4. Planktonic animals.
6. Organisms that it takes a microscope to see.
7. A large, plankton-eating mammal (not a fish).

TEACHER BACKGROUND - Plankton Sampling

Since most of the plankton we will be dealing with are barely visible to the unaided eye, we must use a special net to capture these small creatures. While plankton nets may be purchased in various sizes and at various costs, it is a simple matter to make one. Handmade plankton nets range from the simple to the complex.

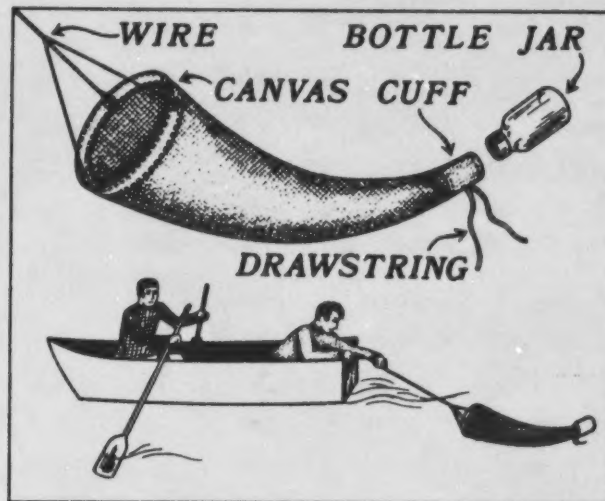


FIGURE 1 A simple method for capturing phytoplankton cells is shown above. Materials for the net are easily obtained. (Oregon State University).

On the next page you will find several methods for constructing plankton nets. Pick the method that best suits your needs and the materials you have available. Any of the nets shown will allow you to capture plankton for study. The more sophisticated nets will allow you to make some estimates of plankton density (number of plankton per unit of water). The methods begin with the simplest and conclude with the most sophisticated.

Method A

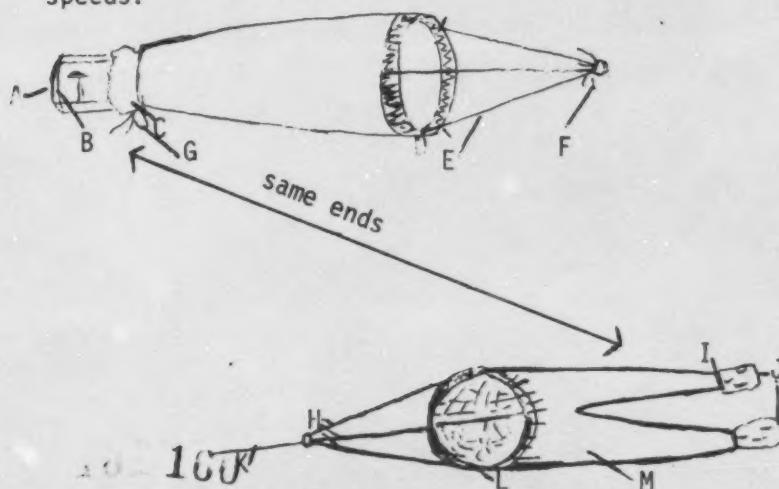
Materials:

ring
 rope, brass chain, or wire
 coat hangers or copper tubing
 wide adhesive tape or string ties
 one or two bottles
 nylon stocking or pantyhose
 heavy string

Procedure:

1. Examine the drawings below.
2. Make a ring the size of the opening of your stocking by bending the copper tubing or several coat hangers wound together. You might find it helpful to make the loop by bending the wire or tubing around a cylinder of the right size. (e.g. a gallon paint can). Embroidery hoops will also serve as an opening ring.
3. Roll the "mouth" of the stocking several times around the hoop.
4. Bind the mouth of your stocking to the ring with the heavy string. (See figure 2)
5. Make a towline by cutting three lengths of rope, each about 50 centimeters in length. Tie the ropes to the ring.
6. Attach your towline to the hoop or to the heavy string.
7. Put a small jar in the toe(s) of the stocking and tie a string around the foot of the stocking at the neck of each jar.

Because the material stretches, changes in towing speed change the mesh size. Slow speeds will have the smallest mesh size. Because of this, you will tend to capture more of the smaller phytoplankton at slow speeds.



- A can
- B plastic chemical bottle with bottom cut out
- C wide adhesive tape
- D copper tubing
- E brass chain for bridle
- F ring
- G sounding weight or anchor
- H bridle
- I string ties
- J bottles
- K tow rope
- L hoop
- M panty hose

Method 2B (From Ron Pruitt, North Carolina Marine Resources Center)

Materials:

Empty gallon bleach bottle

1 square yard fine mesh cloth (cheesecloth, bolting cloth, silk, nylon.

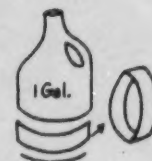
Nylon filters well and does not rot.)

1 small jar with 1" - 2" mouth

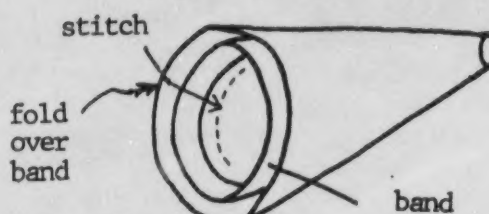
40 - 50 feet strong twine (nylon preferred)

Procedure:

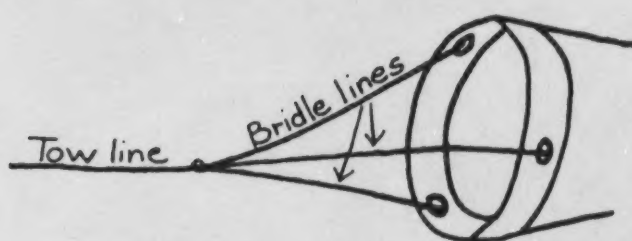
1. Cut a two-inch band from the bottom of the bleach bottle.



2. Shape the cloth conically and sew (leave open at both ends), so that the band may be attached to the larger opening. (If the diameter of the larger opening is made slightly larger than the diameter of the band, you can slip the band into the mouth of the net, wrap the netting around, back through, and stitch



3. Attach three bridle lines and tow line.



4. Attach the jar securely with string and it's done!



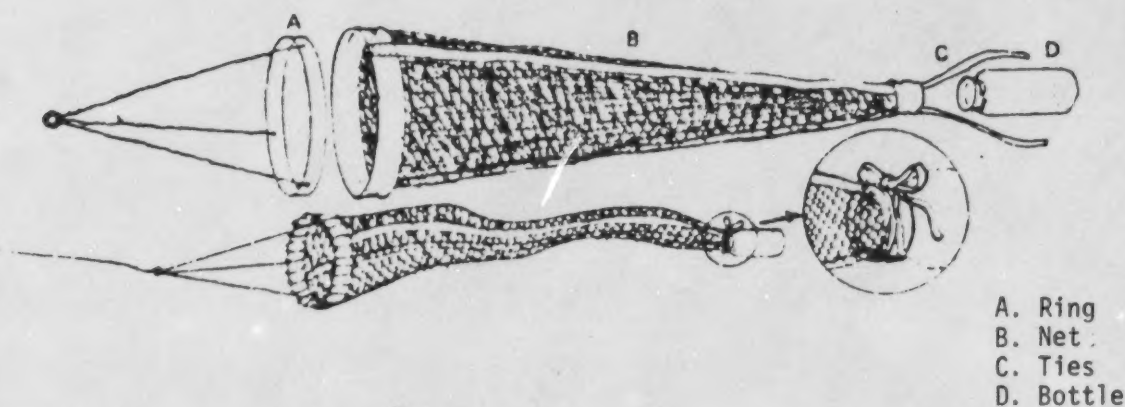
METHOD C

Materials:

ring (20 centimeters to 1 meter in diameter)
 swivel
 steel wire, chain, or rope leaders
 silk bolting cloth or nylon stockings
 canvas
 bottle

Procedure:

1. Obtain a solidly constructed brass, steel, etc. ring with a diameter between 20 centimeters and 1 meter. Attach the steel wire, chain or rope leaders to the ring and to a single swivel at the forward end.
2. Make the net using silk bolting cloth (or nylon stockings) with about 125 - 200 meshes to the inch. (If you use stockings, be aware of the stretching characteristics of the stockings (see method A).)
3. Reinforce the openings with canvas (see figures 7 and 8).
4. Sew two canvas ribbons along the length of the net as shown. The free ends of the ribbons will serve to secure the collecting bottle.
5. Slide your collecting jar to the bottom of the net and tie the jar around the neck with the two free ends of the canvas ribbons. A sturdy plastic or glass bottle with deep threads at the neck is preferred. The size depends upon the net diameter. Plastic mustard or ketchup dispensers, glass cherry, olive or baby food jars are adequate. If a half pint or pint mason jar will work, you can permanently fasten the threaded ring into the net opening so that your collecting bottle can be screwed into place rather than tied.



How To Use Your Plankton Net

Pulling the net behind a slowly moving boat (1 - 2 knots) is a standard method for collecting plankton. Lower the net into the water until the bottle is full and the net is extended. Commence towing. Record the starting time and location so that the distance towed can be recorded. For surface sampling, the net should tow just below the surface. For deeper sampling, tie a weight to a separate line and fasten the line to the front swivel. Bring in the net at the end of the tow and allow it to hang for a few minutes. Wash all of the plankton from the sides of the net into the bottle by running water from the outside of the net.

If a boat is not available, good results can be obtained by towing the net as you walk along on a dock. You can also throw the net from a bridge or pier into a fast tidal current. While these techniques make it more difficult to determine how much water has passed through the net, they will give good supplies of plankton for observation.

TEACHER BACKGROUND - Plankton I, II, III

The world of life available within a drop of sea water can be truly remarkable. In the following exercises your students will use a concentrated plankton sample and magnification to study this world within a world. The study of plankton can provide enough material for a life time of scientific work. These exercises present some of the basic techniques of plankton study and introduce the student to a new world. If time is available or for special projects you may elect to do comparative studies in which:

- a) individual samples are taken from the same area;
- b) samples are taken from different areas;
- c) samples are taken at different times during the day; or,
- d) samples are taken at different depths

The types of projects are limited only by your imagination and the time available.

There are several activities which may be done sequentially. It is also possible to do some of the activities and omit or substitute others. Please read through the procedures and tailor a program that best suits your particular needs. Plankton samples may be taken in any marine or fresh water system. If possible, the sample needed for these activities should be taken in the early morning before school on the day needed. This plan will almost insure students the opportunity to observe living plankton. Place the sample in a large jar or bucket and aerate gently. Be sure to record the distance the net is towed or moved through the water. In addition record and make available to the students the following information:

- a) date and general location of sampling
- b) time of day
- c) wave activity and temperature
- d) tide
- e) depth of sample
- f) diameter of net opening (in meters)
- g) mesh size
- h) estimated distance towed

Each activity requires a separate period for completion. To preserve the sample for use after the first day, 3 - 5% formalin solution is added (1 drop of formalin for every 10 ml of original sample). The first activity, "Plankton I" involves simple observation of the living plankton sample. "Plankton II" involves identification and measurement of plankton. "Plankton III" involves estimating the density of plankton within the water sampled by the plankton net.

In "Plankton III", three methods for determining density are presented. Two methods yield information about the numbers of plankton per unit volume of water and one gives information about the volume of plankton per unit volume of water. It is well to remember that each of these techniques has serious shortcomings. For example, the mesh size will allow smaller organisms to escape. The volume calculations are open to criticism because, in reality, not all of the water through which a plankton net is hauled will pass through the net (some back pressure is caused by net resistance and some water therefore does not enter the net)! The absolute numbers probably have a very slight chance of reflecting what is actually occurring in the sea. These figures are useful, however, in terms of establishing relative abundances of plankton. Relative abundances can be very helpful in determining the productivity of different areas of the sea.

Duplicate the laboratory materials. One set per student is recommended. These exercises are best completed in small groups. Before you begin, review with your class the basics of microscope care and caution them to be careful to wipe up spills on the equipment since salt water is very corrosive. Also review how to estimate the size of objects seen through the microscope. As the exercises are performed, be available to answer questions and be alert to students having problems. Students sometimes tend to have a rather low frustration level for microscopy. This exercise can help overcome these frustrations since the abundance and variety of planktonic organisms is great. Provide an opportunity upon completion of these activities for a discussion of the techniques and to provide the correct answers to the questions presented in the "Analysis and Interpretation" section. The figures provided for identification are not intended to represent a definitive study of the plankton. They provide for only the most general identification. For more complete identification and for additional drawings and aid consult one or more of the following:

Newell, G. E., and R. C. Newell. 1963. Marine Plankton - A Practical Guide. Hutchinson Education. London. 244 pages.

Smith, Deboyd L. 1977. A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae. Kendall/Hunt Publishing Company; Dubuque, Iowa. 161 pages.

KEY

Analysis and Interpretation

Plankton I

1. The copepod crustaceans are the most abundant and widely distributed zooplankton group.
2. Diatoms are the most numerous phytoplankton group.
3. Plankton are important to other life forms in the sea because plankton are at the base of most of the ocean's food chains. All forms of life depend either directly or indirectly upon plankton for their food.
4. Because the drop of water has depth, the plankton can move up and down within the drop. As a result to observe the plankton thoroughly it is necessary to focus the microscope at several different levels. Since the plankton move up and down, the observer must compensate by moving the microscope up and down.
5. The answers depend upon the experimental results. Since the phytoplankton are producers, one would expect them to be more numerous in ocean waters. They may or may not be most numerous in the sample, however, since depth of tow and mesh size are important factors in determining what is captured.

Plankton II

1. The two major groups of phytoplankton are: diatoms and dinoflagellates. Diatoms differ from dinoflagellates in that diatoms have a precise "skeleton" made of silicon while dinoflagellates have a cellulose cell wall. Dinoflagellates also have flagella that are used for movement.
2. The two major groups of zooplankton are: permanent zooplankton and temporary zooplankton. The permanent zooplankton spend their entire existence as drifters while the temporary zooplankton, largely eggs and larvae of various animal phyla, spend only part of their lives as drifters.

3. Crustacean larvae are called "nauplius". The larval names are unfamiliar and confusing. Remind your students that they are venturing into an entirely new and complex world and one that has a terminology of its own.
4. The answer depends upon the experimental results. See number 5 (Plankton I).
5. Since phytoplankton are the producers and zooplankton depend either directly or indirectly upon them for food, one would expect to find more phytoplankton in a plankton sample. The fact that zooplankton are often most common may be an indication of imperfections in the capturing process. The plankton net may not be giving us a random sample of the plankton present in the sea.

Determining the Volume of Water Sampled

1. (a) The number of holes in the net decreases as the net fills with plankton because plankton the diameter of the mesh size will tend to clog the holes.
- (b) It is more difficult for water to pass through the net as the net begins to become clogged.
- (c) The clogged net causes a back pressure that can prevent some of the water from entering the net. As such we are not safe in assuming that all of the water passes through the net. In practice, a small propellor or similar device is mounted at the mouth of the net and used to record the volume of water that actually enters the net. For our purposes the calculations used to determine density assume that all of the water passes through the net.

Determining the Number of Plankton - Method A

1. There are several possible dangers involved in using one species or group (for example, copepods) as an indicator of the abundance of other organisms. The assumption is made that there is a fixed ratio of copepods to other plankton forms. This may or may not be true. The number of copepods is assumed to remain constant over time. The sample is assumed to be representative of the entire planktonic realm. Copepods are assumed to be uniformly distributed. These and other problems which your students will suggest should be discussed in light of the practical considerations involved in counting and identifying all of the myriad organisms present. Sampling one species

as an indicator is a trade off and a calculated risk. This technique is often useful where a rapid determination of the plankton population is necessary.

2. The simplest way to improve the estimate would be to count more squares in the grid.
3. There are many possible sources of error including: recording errors, sampling errors, identification errors, and transcription errors. This is a good opportunity to discuss the procedure and possible problems encountered with same.
4. The answers depend upon the experimental results. It is possible but unlikely that all of the results are the same. The variation can provide material for a discussion of statistical sampling and of the value of sampling more than three grid squares to obtain a more reliable result.
5. Answer depends upon experimental results.
6. The class average will tend to be more accurate than any of the individual estimates since the averaging process minimizes the high and low estimates and is based on a larger sample size.

Determining the Number of Plankton - Method B

1. The largest plankter that could fit through the pores of the type H. A. Grid filter would have a diameter slightly less than 0.45 microns.
2. Steps 3, 4, and 5 are concerned with assuring that the small sample taken with the pipette is representative of the larger sample.
3. While it is possible that all of the results are the same, it is not likely. Again, there are many sources of error that might account for the differences. For example: incomplete mixing, counting errors, observation errors, recording errors, a non-uniform distribution of the sample on the grid, etc. Use this opportunity to discuss the types of errors that can occur in an investigation like this.
4. Answer depends upon experimental results.
5. The class average will tend to be more accurate than any of the individual estimates since the averaging process minimizes the high and low estimates and is based on a larger sample size.

6. The answer depends upon experimental results. One would expect Method II to yield higher figures since it is an estimate of the total plankton population while Method I only counts copepods. You may find, however, that expectations and reality do not coincide. If the two methods were employed on different samples, the results may vary widely.

Determining the Volume of Plankton

1. Errors in reading the volumes, calculation errors, recording errors, incomplete settling, etc. are all possible sources of error that might influence the results obtained.
2. Method I (counting over a grid) and Method III (volume) would allow further study of the plankton after the number or volume is determined.
3. Method III which determines the volume of plankton would be most useful to Captain Greengenes since it is the easiest and most quick method to determine relative abundances. The relative abundance of plankton in the three areas is what the captain is interested in determining.
4. Dr. Goodenough needs to determine not only the relative abundance of plankton but also differences in species composition between the areas. As such Method II would probably be preferred although Method II tends to make identification of the different types difficult. The good doctor would probably need to use a variety of methods to achieve his goals.
5. Plankton numbers and densities are important as an indicator of the health of the oceans and their productivity. Since plankton are the basis for all life in the sea, their health determines the health of the ocean ecosystem.

KEY WORDS

abundance
annelid
average
bipennaria larvae
calanoid copepod
calculate
cellulose
coelenterate
copepods

cyclopoid copepod
crustaceans
density
diatoms
dilution factor
dinoflagellates
echinoderms
estimate
flagella
forceps
formalin
grid
harpacticoid copepod
immersion oil
indicator species
invertebrate
isotonic salt solution
juvenile
larvae
micron
Millipore Filtration Appartus
molluscan
nauplius larvae
organism
permanent zooplankton
phytoplankton
pipette
plankton
planula larvae
platyhelminth larvae
populations
productivity
radius
range
silicon

suction
syringe
temporary zooplankton
test
trochophore larvae
unbiased
veliger larvae
volume
zooplankton

PLANKTON I, II, III

Nearly every creature in the sea spends either a part or all of its life drifting about. If we add these "part time" drifters to those plants and animals that spend their entire existence as drifting plankton we see a population of organisms so immense that it defies counting. In this exercise you will have an opportunity to examine this vast assemblage of plankton. While you will be observing microscopic plankton, remember that some of the plankton are as large as two or three feet. Among the members of the animal plankton (zooplankton) eggs, larvae, and juvenile forms of most invertebrates and fishes are common. Copepod crustaceans (related to crabs and shrimp) are the most abundant and widely distributed zooplankton.



ZOOPLANKTON



PHYTOPLANKTON

Phytoplankton (plants) are more numerous than zooplankton and are best represented by the diatoms that form the vast bulk of the ocean's vegetation.

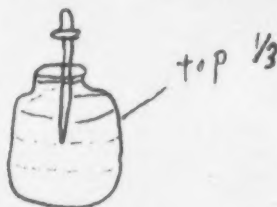
Plankton form the basis of life in the sea. All forms of life in the marine world depend either directly or indirectly upon them for food. Without plankton the seas would be barren. In this activity you will have a chance to observe and analyze a sample of these dynamic little creatures.

Materials:

compound microscope
dissecting microscope
petri dish
slide and cover slip
eye dropper
sample bottle and label
concave slides
preservative (3 - 5% formalin)
plankton sample

Procedure:

1. The teacher will provide the recorded conditions under which the plankton sample was made. Enter this information on the data sheet provided.
2. Use the eye dropper to draw up a few drops of the concentrated plankton. Take the sample from the top one third of the bottle of concentrated plankton.



3. Place one drop in each of four or five locations on your petri dish.

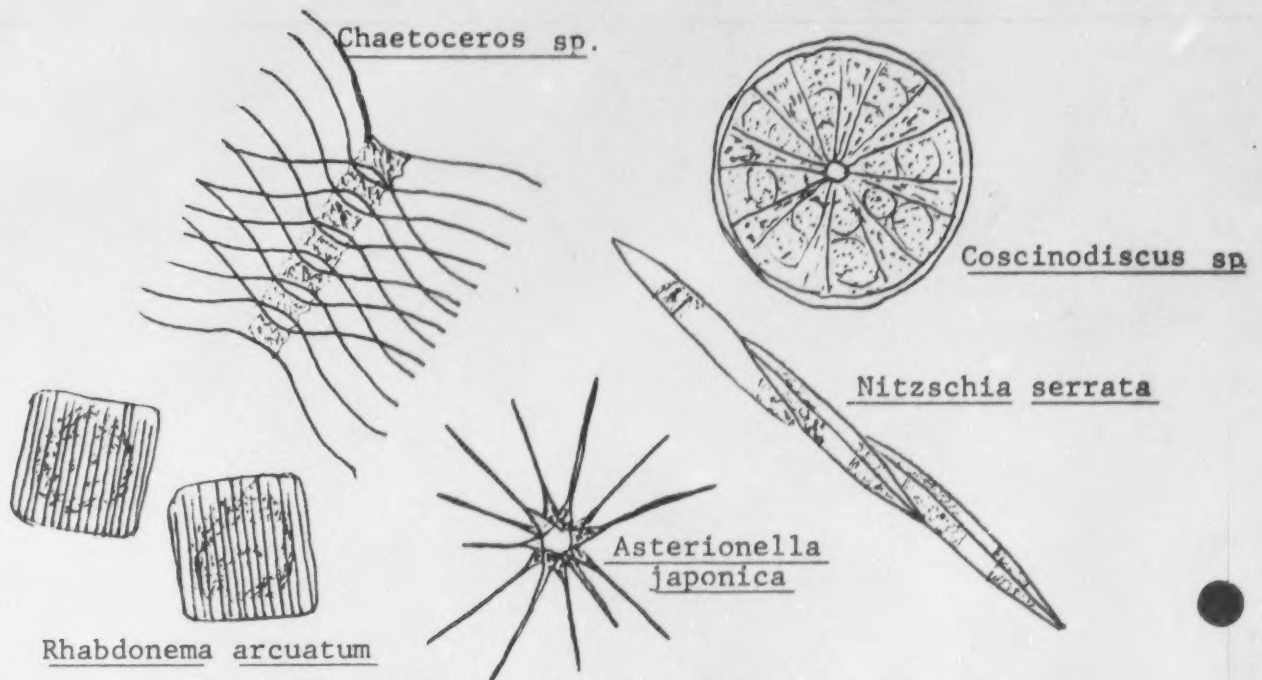
4. Observe each drop with a dissecting microscope. Since the plankton can move up and down in the drop, you will need to focus up and down with your microscope to see the plankton at different levels.
5. Many organisms are too small to be seen with the dissecting scope. Prepare wet mounts of the sample and observe under a compound microscope with low and high power objectives. Do not discard any part of the sample. Empty wet mounts back into petri dish. Rinse with medicine dropper of water.
6. Do not record any observations today. Look for:
 - a. most abundant organisms
 - b. variations in shape, color and swimming abilities
 - c. types of appendages
 - d. chlorophyll-containing organisms
 - e. eggs
 - f. larval and juvenile forms of crustaceans and and fish (see pictorial guide to the plankton, which follows).
7. Preserve sample in 3-5% formalin before leaving. Use three drops of formalin per 120 ml of plankton sample. Label sample bottle with your name and period.

Plankton II - Identification

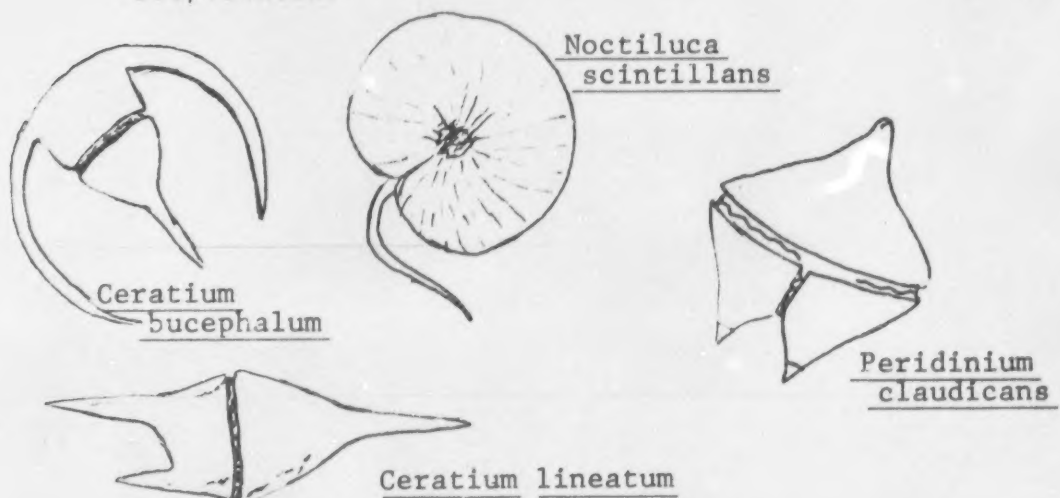
The two major divisions of plankton are phytoplankton (plants) and zooplankton (animals). Within these two groups exist a number of subgroups:

- I. Phytoplankton - able to produce their own food through photosynthesis

- A. Diatoms - often called the golden-brown algae have a transparent silicon skeleton called a test. The tests have a precise geometric design.

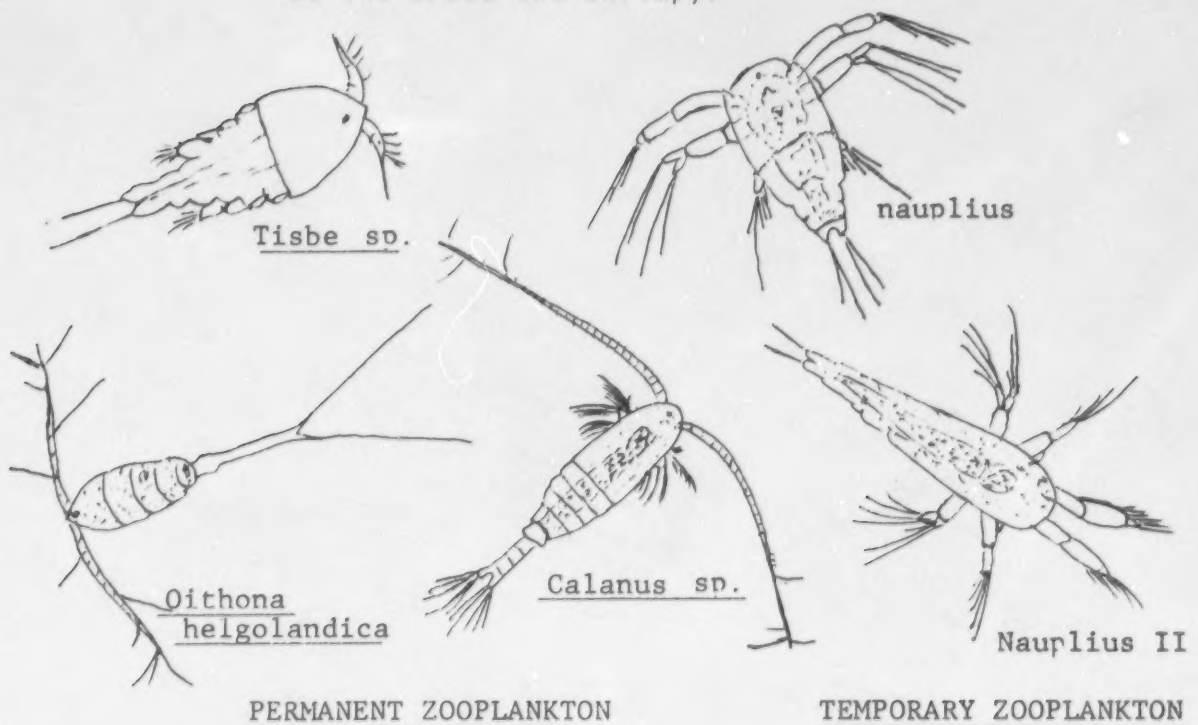


- B. Dinoflagellates - have a cellulose cell wall and, in most species, two whip-like flagella used for mobility. Because of their ability to move and other characteristics some zoologists think these organisms should be classed as zooplankton.



II. Zooplankton - Obtain their food by eating phytoplankton or other zooplankton. All of the major groups of animals are found within the zooplankton.

A. Permanent zooplankton - spend their entire existence as drifters. Most of the permanent zooplankton, including the numerous copepods, are crustaceans (belonging to the same group as the crabs and shrimp).



B. Temporary Zooplankton - spend part of their life cycle as drifters. The most common temporary zooplankton are the larvae (in some ways equivalent to "baby") forms of the following groups:

(Note: each larval form has one or more specific, descriptive terms which are underlined).

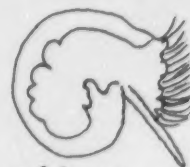
1. Coelenterate (corals, jelly fish, sea anemone)
larva - planula larva
2. Platyhelminth (flatworms) larva - Müller's larva
3. Molluscan (snails, clams, chitons) larva -
veliger larva
4. Annelid (segmented worms) larva - trochophore
larva
5. Crustacean (barnacles, crabs, shrimp) larva -
nauplius
6. Echinoderm (sea star) - bipinnaria larva



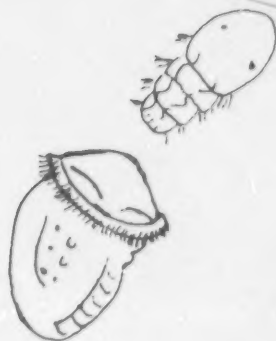
planula of coral



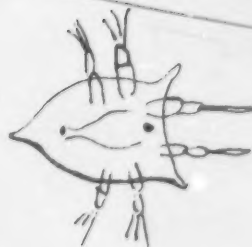
Müller's larva



veliger



trochophore larva



nauplius



bipinnaria larva

The descriptions on the preceding page and the figures which follow will help you identify the organisms in your plankton sample.

Materials:

preserved plankton sample
compound microscope
slides and cover slips
ruler

Procedure:

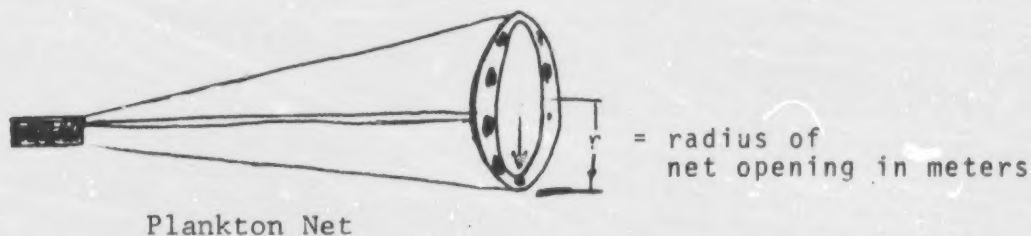
1. Select the most common organism from your preserved sample.
Prepare a wet mount and view with low power (or high power).
2. Record the following information on data sheet
 - a. a detailed penciled drawing of the specimen
 - b. measured actual size, in microns
 - c. measured drawing size, in microns
 - d. magnification of drawing (equals $\frac{\text{size of drawing}}{\text{actual size of animal}}$)
 - e. identification
3. Repeat this procedure with as many different specimens as time permits. Do at least:
 - a. two different kinds of phytoplankton
 - b. four different kinds of zooplankton
 - c. include at least one diatom, one dinoflagellate, and one permanent zooplankton form.Record all observations on your data sheet.
4. Do not discard any portion of your sample. Empty wet mounts back into sample bottle. Rinse with dropper of water.

PLANKTON III - Density

Populations of individual plankton species may vary considerably during the course of a year. As the waters warm in the spring and summer, many larval forms of invertebrates and fish appear in great numbers. It is important for biologists to study these changes to obtain information about the productivity of the waters sampled. Productivity is related to the density of plankton (number of plankton in a given volume of water) and gives biologists an idea of how much life an area will support. In this activity you will determine the density of plankton in terms of the number of plankton or the volume of plankton per cubic meter of sea water.

Determining the Volume of Water Sampled

To compute the volume of water sampled as you towed your net through the water, you will need to know the total distance towed and the diameter of the opening of the net. Use the following diagram, formula, and example to help you.



$$\begin{array}{l} \text{Volume of water} \\ \text{sampled in cubic} \\ \text{meters (M}^3\text{)} \end{array} = \frac{\pi(\text{radius})^2}{\text{of net opening}} \times \begin{array}{l} \text{(total distance} \\ \text{towed) in} \\ \text{meters} \end{array}$$

Example:

Total Distance of Net Tow	10 M
Diameter of Net in Meters	0.24 M
Radius of Net in Meters = $\frac{\text{diameter}}{2}$	0.12 M

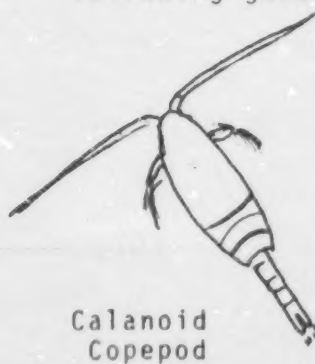
$$\begin{aligned}
 \text{Volume of Water sampled in M}^3 &= \pi r^2 (\text{tow distance in meters}) \\
 &= \frac{(22)}{7} (.12\text{m})^2 \times (10\text{m}) \\
 &= \frac{(22)}{7} (.0144) \times (10\text{m}) \\
 &= 0.4526 \text{ M}^3
 \end{aligned}$$

1. Now calculate the volume you sampled:

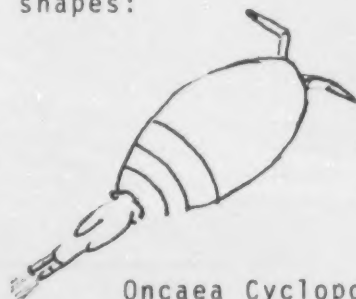
2. Record the volume on your data sheet.

Determining the Number of Plankton - Method A

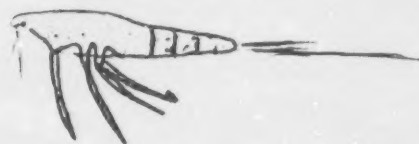
Because of the difficulty encountered in attempts to count all of the different sizes and kinds of plankton species in a sample, we will estimate the abundance of a single type of plankton, the copepod. Copepods are the most abundant and obvious representatives of the surface plankton. We will use the copepod as an indicator species. Copepods have the following general shapes:



Calanoid
Copepod



Oncaea Cyclopoid
Copepod



Microsetella
Harpacticoid Copepod

Materials:

petri dish
 centimeter grid or centimeter graph paper
 dissecting microscope (10x)
 plankton sample

Procedure:

1. Pour your sample (1 ml or 5 ml) into a petri dish.
2. Determine the area of the dish by using the following

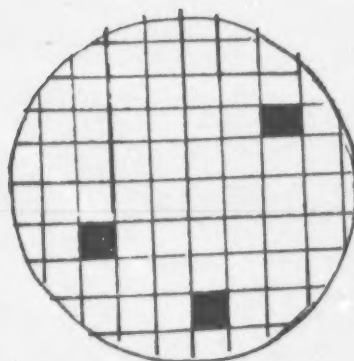
formula:
$$A = \frac{\pi D^2}{4}$$

Where: A = number of sq. centimeters covered
 by dish

$$\pi = \frac{22}{7}$$

D = diameter of dish in centimeters

3. Place petri dish over a centimeter grid or graph paper with centimeter squares clearly marked. Distribute sample evenly over bottom of dish.
4. Count the number of copepods in any one square and multiply by the total number of squares (area) present; you will then have an estimate of the total number of organisms in the dish. Record this number on your data sheet.
5. In order to determine a more accurate count, select the three squares indicated in the diagram.



The 3 pre-selected squares will give an "unbiased" count. To find the average number per square, divide the total number of copepods in the three squares by three. Multiply your average by the total number of squares (area) in the dish to obtain an estimate of the total number of organisms in your dish.

For example: 66 copepod organisms were counted in the 13 grids. The area of the dish covered 63.5 squares or 63.5 cm²

$$\begin{aligned}
 \text{Total number of copepod organisms} &= \frac{\text{no. counted in 3 grids}}{3} \times \text{no. of square (Area)} \\
 &= \frac{66}{3} \times 63.5 \\
 &= 1397 \text{ copepod organisms on the sample}
 \end{aligned}$$

6. Compute total of copepod organisms in original concentrated sample: $Q = T \times \frac{V}{v}$

where. . . .

Q = total copepods passing through plankton net.

T = total number of copepods in your sample.

V = total volume of original concentrated sample.

v = volume of your sample

for example. Ten (10 ml) of sample was strained from 30 cubic meters (M^3) of sea water. You received 1 ml of this and proceeded to count 1397 copepod organisms/

30 M^3

7. Compute the total number of copepod organisms per cubic meter.
8. Record all information on data sheet.

Determining the Numbers of Plankton - Method B

Method II is a more refined way to determine plankton numbers. As with Method A the numbers of plankton in a small sample are determined. The small sample is assumed to be representative of the plankton collected in the net. The equipment used in this experiment must be handled with care.

Materials:

Previously collected plankton samples
 Millipore Filtration Apparatus
 H. A. Grid Filters with a 0.454 pore size
 300 ml of isotonic saline solution
 Forceps
 Immersion oil
 Petri dish
 Monocular microscope or dissecting microscope
 1 - 1 ml pipette

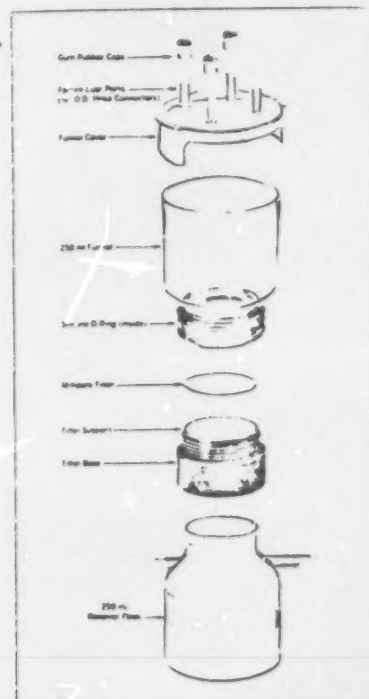
Procedure:

1. Prepare a Millipore Filtration Apparatus using a Type H. A.

Grid filter with a 0.454 pore size.

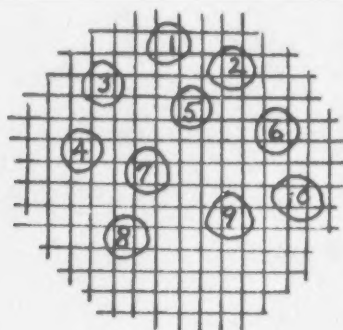
(A detailed description of the apparatus may be found in the activity: "Analysis of Water for Bacterial Pollution".)

Millipore Filtration Apparatus →



2. Add approximately 100 ml of isotonic salt solutions to the top portion of the filtration apparatus.
3. Shake the plankton sample well to insure that the plankton are uniformly distributed and quickly pipette out 1.0 ml.
4. Add the 1.0 ml sample into the filtration apparatus. Rinse the pipette with isotonic salt solution to make certain that all the plankton are transferred into the apparatus.
5. Swirl the salt solution and sample carefully to insure uniform mixing.
6. Using the syringe, suction the water into the lower part of the filtration apparatus.
7. Rinse down the sides of the upper half of the filtration apparatus with approximately 50 ml of salt solution to insure that no plankton adhere to the sides.
8. Again using the syringe, suction the solution through the filter. This will leave the plankton evenly distributed on the filter surface.
9. Open the filtration apparatus and carefully remove the filter using the forceps. Place the filter on a towel or blotting paper, plankton side up, to dry. This should take approximately 5 minutes.
10. When dry, take a ballpoint pen and circle the samples

as shown below. Be careful to make your circles large enough so they do not come near any line on the square you will count.



11. Float your filter on a thin layer of immersion oil in a clean petri dish. This will render it transparent for microscope use.
12. Transfer the filter to a glass slide for counting the particles in each sample square.
13. Use low power of your microscope. If a part of an organism touches the top or lefthand line of the square, count it; if it touches the bottom or righthand line of the square, do NOT count it. Why is this necessary? Tabulate the number of plankton in each square. RECORD your results on your data sheet.

NOTE: At this point, you may observe that the plankton are so densely packed that you cannot obtain an accurate count. If this is the case, it will be necessary to go back to step 4. Decide how much greater a dilution will be necessary to provide you with a sufficiently diluted sample. If you wish to dilute by 10% more, take a well mixed 10 ml portion of the previously diluted plankton sample you prepared and place it in 100 ml graduated cylinder -- add saline to the 100 ml mark.

If you find that there are too few organisms on the filter, go back to step 5 and proceed. Instead of taking a 1.0 ml sample from the plankton sample take the necessary amount which will give you a reasonable number of organisms to count, i.e., if you wished to increase the number 10 fold, take 10 ml from the plankton sample and add this to the filtration apparatus.

14. The number of plankton counted are then multiplied by a number to calculate the count which would have been found had the entire surface of the filter been scanned. This formula is:

$$\frac{145}{10 \text{ grid squares counted}} \times \text{Number of Plankton} = \text{the number plankton on the filter}$$

15. RECORD this figure as the total number of plankton on the filter

EXAMPLE: If 22 plankton were counted on the ten grid squares:

$$\frac{145}{10} \times 22 = 319 \text{ Plankton on Filter}$$

For your sample:

$$\text{Total number of plankton on filter} = \frac{145}{10} \times \frac{\text{total}}{\text{(\# you counted)}}$$

16. Knowing the number of plankton on the filter, it is easy to estimate the number in the original sample by multiplying the number on the filter by the *Dilution Factor*. The dilution factor is determined by dividing the original sample volume by the size of sub-sampled you pipetted (either 1 ml or 5 ml).

EXAMPLE: If 1 ml was pipetted from a sample with a volume of 100 ml, the dilution factor would be:

$$\text{Dilution factor} = \frac{\text{sample volume}}{\text{pipette volume}}$$

$$\text{Dilution factor} = \frac{100 \text{ ml}}{1 \text{ ml}}$$

$$\text{Dilution factor} = 100$$

Plankton II

PLANKTON LABORATORY
Data Sheet

A. Record the following conditions pertaining to the sample under study.

1. date _____ 4. tide _____ 7. diam. net opening _____ meters
 2. location _____ 5. depth _____ 8. distance net towed _____ meters
 3. time of day _____ 6. mesh size _____

phytoplankton

zooplankton

diatom

dinoflagellate

permanent
zooplankton

organism #	1	2	3	4	5	6
drawing						
actual size						
drawing size						
magnification						
identification outstanding features? coloration? common and/or scientific name						

Determine the total number of plankton in the concentrated sample.

$$\text{Number on the filter} \times \text{Dilution Factor} = \text{Number of Plankton in the concentrated sample}$$

EXAMPLE: If the dilution factor was 100 for the example above:

$$319 \times 100 = 31,900 \text{ Plankton in concentrated sample}$$

17. To calculate the Number of Plankton/M³, simply divide the number of plankton in the sample by the volume of water sampled originally.

Formula:

$$\frac{\text{Number of Organisms in Sample}}{\text{Volume of Sample in M}^3} = \frac{\text{Number of Organism}}{\text{M}^3} = \text{Density}$$

EXAMPLE: If .4526 M³ is the volume of water sampled:

$$\frac{31,900}{0.4526 \text{ M}^3} = 70,481 \text{ Plankton/M}^3$$

Calculate the Density of Plankton.

$$\text{Density} = \frac{\text{Number of Organisms}}{\text{M}^3} = \frac{\text{Number of organisms in sample}}{\text{Volume of sample in M}^3}$$

$$\text{Density} = \frac{\text{_____}}{\text{_____}} \begin{matrix} \text{(your number)} \\ \text{(your volume)} \end{matrix}$$

$$\text{Density} = \frac{\text{_____}}{\text{_____}}$$

Record your density on your data sheet.

Determining the Volume of Plankton

The volume of plankton can be determined by settling. The preserved plankton sample is allowed to settle in a graduated cylinder. The results obtained using this method have some inherent inaccuracies. Nevertheless, the technique gives some idea of plankton abundance and is useful for comparing plankton densities in various areas. It is also simple and fast.

Materials:

plankton sample (preserved in 3-5% formalin)
graduated cylinder (size depends upon size of sample)

Procedure:

1. Pour the sample into a graduated cylinder and let the sample settle for at least one hour. You can allow the sample to settle until the next class period if the schedule allows.
2. Read and record the volume of the plankton settled (in millimeters) _____ millimeters of plankton.
3. Plankton abundance may be calculated by dividing the volume of plankton in millimeters by the volume of water sampled in cubic meters:

$$\text{Plankton abundance} = \frac{\text{volume of plankton}}{\text{volume of water sampled}}$$

Calculate and record the plankton abundance for your sample:

$$\text{Plankton abundance} = \frac{\text{Volume of plankton}}{\text{volume of water sampled}} = \underline{\hspace{2cm}}$$

+

$$\text{Plankton abundance} = \underline{\hspace{2cm}} \text{ 1941/M}^3$$

Analysis and Interpretation:

Plankton I

1. Which zooplankton group is most numerous?
2. Which phytoplankton group is most numerous?
3. How are plankton important to other life forms in the sea?
4. When observing living plankton in drops of water why is it necessary to move the microscope up and down while focusing?
5. From your observations, which kind of plankton (zooplankton or phytoplankton) seemed to be most numerous?

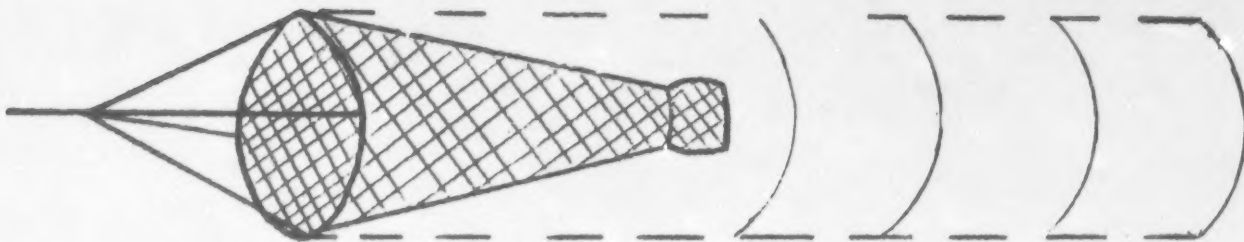
Plankton II

1. What are the two major groups of phytoplankton? How do they differ?
2. What are the two major groups of zooplankton? How do they differ?
3. What are crustacean larvae called?
4. Which organism was most common in your sample? Is it a phytoplankton or zooplankton?

5. Which would you expect to be most common in a plankton sample, phytoplankton forms or zooplankton forms? Explain.

Determining the Volume of Water Sampled

1. The calculations that you performed gave you the volume of a cylinder, the diameter of your net and the length of the tow.



Cylinder of Water Sampled

This assumes that all of the water passes through the net.

- (a) What happens to the number of holes in the net as the net begins to fill with plankton?
- (b) It is (easier) (more difficult) for water to pass through the net as the net begins to become clogged. (Cross out wrong choice.)
- (c) In view of your answers to (a) and (b) above, how safe are we in assuming that all of the water passes through the net? Explain.

Determining the Number of Plankton - Method A

1. What is one possible danger of using copepods as an indicator species in determining plankton abundance?
2. How could you improve your estimate of the total number of copepods using the same technique?
3. What are two possible sources of error inherent in this procedure?
4. Compare your results with those of others in your class. For the same sample, what is the range of estimates? (The range is the difference between the highest estimate and the lowest estimate).
5. Calculate a class average for your estimates of the total number of copepod organisms per cubic meter.
6. Is the class average more or less likely to be accurate than your individual estimate? Explain.

Determining the Number of Plankton - Method B

1. What is the largest plankter that could fit through the pores of the Type H. A. Grid filter?
2. Which steps of the procedure are concerned with making sure the small sample taken with the pipette is representative of the larger sample?

3. Compare your results with those of others in your class. Are all of the results the same? If not, what are two possible sources of error that might account for the differences?
4. Calculate a class average for your estimates of the total number of organisms per cubic meter.
5. Is the class average more or less likely to be accurate than your individual estimate? Explain.
6. If you also did the procedure outlined in Method A, how do your results from Method A compare with your results using Method B. How can you explain any differences between the estimates?

Determining the Volume of Plankton

1. As with any experiment, there are many possible sources of error in this activity. What are two sources of error that might influence the results obtained?
2. Which of the three procedures outlined in Plankton III would allow further study of the plankton after the number or volume is determined?
3. To improve his fish take, Captain Greengenes is interested in determining the plankton abundance in three different areas. He is most interested in finding the area with the greatest abundance of plankton. Which method of the three procedures outlined in Plankton III would you recommend that he use? Why?

4. Dr. Goodenough is studying the effect of the discharge of hot water on the numbers of plankton. He wants to sample plankton at various distances from the outflow. Which method of the three procedures outlined in Plankton III would you recommend that he use? Why?

5. What is the major reason people are interested in determining plankton numbers and densities?

Plankton III

Data Sheet

A. Record the following conditions pertaining to the sample under study:

1. date _____ 4. tide _____ 7. mesh size _____
 2. location _____ 5. depth _____ 8. diam. net opening _____ meters
 3. time of day _____ 6. tow time _____ 9. distance net towed _____ meters
 10. dilution of your sample _____ 11. volume of your sample _____ ml

B. Determining the Volume of Water Sampled

$$\text{volume of water sampled (M}^3\text{)} = \pi \text{ radius of net (M)} \times \text{distance towed (M)}$$

$$\text{volume} = \pi (\text{M}) \times (\text{M})$$

$$\text{volume of water sampled} = \text{M}^3$$

C. Determining the Number of Plankton - Method I

1. Total number of copepods = (Number in one square) x (Number of squares in dish)
 Total number of copepods in dish = _____ x _____
 Total number of copepods in dish = _____
2. Total number of copepods = $\frac{\text{Number counted in 3 grids}}{3} \times \text{number of squares (area)}$
 Total number of copepods in dish = _____ x _____
 Total number of copepods in dish = _____
3. Total number of copepods in original concentrated sample = $\frac{(\text{Total number of copepods in dish}) \times (\text{Volume of original concentrated sample})}{\text{Volume of your sample}}$
 Total number of copepods in original concentrated sample = () x $\frac{\text{----- ml}}{\text{----- ml}}$
 Total number of copepods in original concentrated sample = _____
4. Number of copepods per cubic meter = $\frac{\text{Total number of copepods in original sample}}{\text{Volume of water sampled (from B above)}}$
 Number of copepods per cubic meter = $\frac{(\text{-----})}{(\text{-----M}^3)}$
 Number of copepods per cubic meter = _____

D. Determining the Number of Plankton - Method II

- square number
1. Number of plankton in each square:
- | | |
|---------|----------|
| _____ 1 | _____ 6 |
| _____ 2 | _____ 7 |
| _____ 3 | _____ 8 |
| _____ 4 | _____ 9 |
| _____ 5 | _____ 10 |
2. Total number of plankton on filter = $\frac{\text{Number of plankton counted (sum of 1 to 10)} \times 145 \text{ grid squares in dish}}{10 \text{ grid squares counted}}$
 Total number of plankton on filter = _____ x $\frac{145}{10}$
 Total number of plankton on filter = _____
3. Dilution factor = $\frac{\text{sample volume}}{\text{pipette volume}}$
 Dilution factor = $\frac{(\text{-----ml})}{(\text{-----ml})}$
 Dilution factor = _____
4. Number of plankton in the concentrated sample = (Total number of plankton on filter) x (Dilution factor)
 Number of plankton in the concentrated sample = _____ x _____
 Number of plankton in the concentrated sample = _____
5. Number of plankton per M³ = $\frac{\text{Number of plankton in the concentrated sample}}{\text{Volume of water sampled (from B above)}}$
 Number of plankton per M³ = $\frac{(\text{-----})}{(\text{-----M}^3)}$
 Number of plankton per M³ = _____ = Density

E. Determining the Volume of Plankton

1. Volume of plankton settled = _____ ml of plankton
2. Plankton abundance = $\frac{\text{volume of plankton}}{\text{volume of water sampled}}$
 plankton abundance = $\frac{(\text{-----ml})}{(\text{-----M}^3)}$
 plankton abundance = _____ ml/M³

TEACHER BACKGROUND - Whales, Plankton, and Man - Three Level Guide

The idea of the oceans as a boundless source of food for man is debated both in and out of the scientific community. On one hand it is clear we are overfishing certain species and jeopardizing the existence of others through pollution. On the other hand, the ocean is a vast storehouse of life. In "Whales, Plankton, and Man", your students will have a chance to see part of the debate and to also see how a scientific theory is formulated and put out for others to see and comment upon. The merit of this article lies more in what it reveals to us about the scientific process than in the absolute subject matter. Since one of the prime reasons whaling nations continue to whale is the large capital investments they have in fishing equipment, the idea of shifting the pressure from whales to krill has some appeal for whale supporters. Unfortunately, the theory does not seem to have won widespread acceptance among the whaling nations.

This article is difficult reading for many students. This article seems to typify a problem seen in teaching today; we can have articles that cover the material but are too difficult to read or we can have articles that can be read but do not cover the material. The three level guide presented here is one way to solve this seeming dilemma. Three level guides are based on what seems to be the general agreement that comprehension can take place at different levels of cognition. Harold L. Herber has called these levels 1) literal; 2) interpretive; and 3) applied. With the exception of the literal level, each level requires the product of the previous level or levels in order to function. The literal level of comprehension produces knowledge of what the author said. We all recognize that it is quite possible to identify and even repeat what an author has said without understanding what the author meant by his statements. The interpretive level of comprehension depends upon the reading performed at the literal level but carries the process a step further. At this level the reader derives meaning from what the author has said. The meaning is determined by the way the reader perceives the intratext relationships. The applied level of comprehension takes the product of the literal, (what the author has said) and the interpretive (what the author meant by what he said) and applies it in some practical or theoretical exercise. At this level the reader is using his past experiences and knowledge to produce new ideas which extend beyond

those immediately identifiable in the reading selection. It must be borne in mind that the level at which a person reads does not reflect upon her intelligence and that the level can change as the material changes. The most advanced engineers and scientists often read at the literal level if they cross into other disciplines. When we read materials from an area with which we have little familiarity, our level of comprehension goes down. Your students are no exception to this observation. The three level guide is a device used to improve a person's comprehension by focusing on important concepts at each of the three levels. The three level guide can be used with any material and is readily constructed. For aid in this regard please see:

Teaching Reading in the Content Areas. 1970. Harold L. Herber.
Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 296 pages.

Duplicate the pages of the three level guide; One set per student. Spend a few minutes describing what is expected of the student. Suggest that the students read the statements in the three level guide before they read the article. In this way, the statements serve as a preview and your students will be looking for and expecting to see certain concepts. You may elect to have your students compare their answers by meeting in small groups. The process of resolving differences in opinion can be very instructive. Upon completion of the reading of the three level guide, discuss the guide by reference to the article. It is sometimes helpful to have your students note the page number and paragraph number where they found evidence supporting or refuting the statements in the guide. You can require your students to provide this information or you can offer extra credit for those that include it. Choose the technique that most appeals to you and best fits the needs and skills of your class.

KEY WORDS

analyzing

baleen whales

calories

diatoms

food chain

generalization

interpretations

interrelated
krill
organic matter
paraphrased
photosynthesis
plankton
producers
resolve
utilization

KEY

WHALES, PLANKTON, AND MAN - Three Level Guide

Level 1. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those that you believe say what the author actually said or paraphrased in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference. Also, be ready to explain what is inaccurate about the statements that you do not check.

- ☐ The whale feeds directly upon the plants of the sea.
- ☒ The single-celled diatoms conduct the major portion of the photosynthesis that goes on in the oceans.
- ☒ In each step of a food chain between 80 and 90% of the organic matter and hence the energy is lost.
- ☐ Baleen whales depend upon medium and large sized fish for their food.
- ☒ Shrimplike krill are plant plankton eaters that bring the baleen whale to within one step of the producers.
- ☒ To serve as a food for man, krill would have to:
(1) supply our nutritional requirements (2) be tasty
(3) be abundant.
- ☒ Adult whales need about one million calories per day.
- ☐ Adult whales need to eat about 600 to 800 pounds of krill per day.
- ☒ The two hundred fifty ships and 16,000 men who make up the largest whaling fleet in history might find it more profitable to fish for krill.

Directions: Now compare your answers with those of others in your group. If there are many differences, find the page and paragraph that support your answer and write them next to the statement in question. When you finish your discussion, go on to the next level.

Level II. Directions: The statements below may or may not be true. Check each statement you believe is a generalization the author himself draws based on the information he gives in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference.

- ☒ The plant plankton numbers are maintained in check by several interrelated factors.
- ☐ Whales and man face very different problems in obtaining sufficient food.
- ☒ A food suitable for maintaining baleen whales would have to be very numerous.
- ☒ It is time to re-evaluate the economics of whaling and krill fishing.
- ☐ Efficient production can yield 100 to 250 pounds per acre per year.
- ☒ Since krill feeds directly upon plant plankton, its use as a food would be energy efficient.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to next level.

Level III. Directions: Read each statement below, relating the details and author's interpretations drawn from the selection to ideas and experiences you've had in reference to this topic. In column A, check the statements which Pequegnat would have agreed with. In column B, check the statements you agree with.

- | A | B | |
|-------------------------------------|--------------------------|--|
| ☒ | ☐ | The food resources in the sea offer a real challenge to mankind and a possible source of additional protein. |
| ☒ | ☐ | If man is to survive in ever increasing numbers, we will have to concentrate on food species closer to the beginning of the world's food chains. |
| ☒ | ☐ | It is possible to determine the abundance of animals by analyzing the stomachs of predators on these animals. |

☒ _____ New and creative approaches to our utilization
of ocean resources are needed.

☒ _____ Krill fills the bill.

Directions: Again, compare your answers with your group.
Where there are differences, try to resolve
them.

WHALES, PLANKTON, AND MAN

WILLIS F. PEQUEGNAT

January 1958

Among the "whale statements" in the prefatory pages of *Moby Dick* we find a quotation from Obed Macy's *History of Nantucket* which reads: "In the year 1690 some persons were on a high hill observing the whales spouting and sporting with each other, when one observed; there—pointing to the sea—is a green pasture where our children's grandchildren will go for bread."

Many people who are actively concerned with mankind's food problem think it is high time we made the Nantucketer's prophecy good. Of course to bake literal loaves of bread from seaweed would take some doing. But the whale feeds upon the plants of the sea only indirectly (by eating small herbivorous animals), and what is food for whales could also be food for man. The whale bears compelling testimony to the abundance of the ocean pasture. The sea is estimated to be as productive of organic food, acre for acre, as the land. With 70 per cent of the globe covered by oceans, in the aggregate the sea must produce five to 10 times as much living matter as the land. Yet we take only 1 per cent of our food from this source. Considering that half the world population lives on the edge of starvation and that we must feed 100,000 additional mouths every day, the sea's food potential cannot be neglected much longer.

We could, to begin with, increase our harvest from the sea by more intensive fishing for the conventional game. But I want to propose here a new kind of fishing which could be far more productive. My proposal admittedly is based on some purely theoretical deductions. But even if these deductions are only partly borne out, we may be able to open up at once a vast source of palatable high-protein food.

The whale's pasture is the upper, sun-

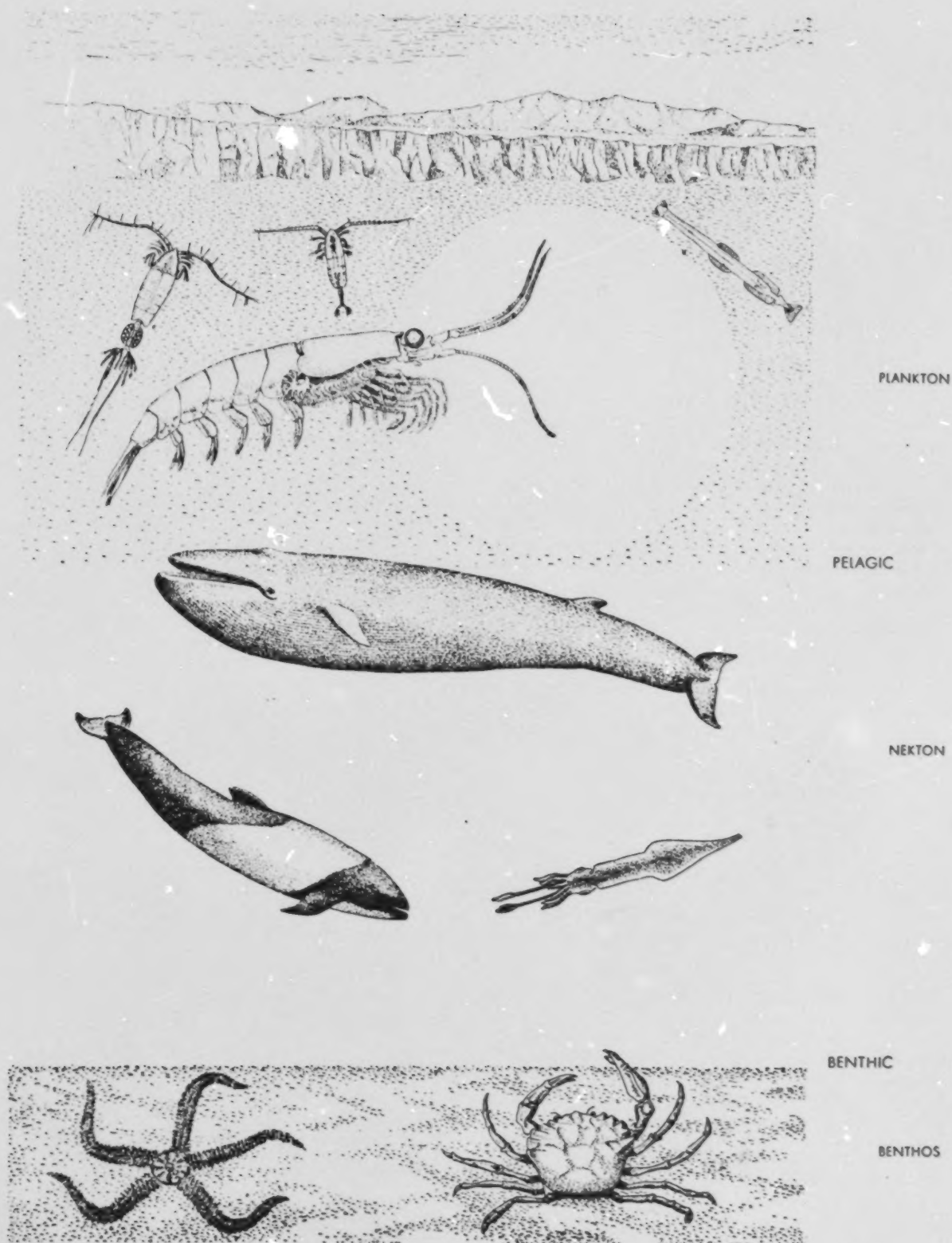
lit layer of the open ocean. The plant life of this zone consists mainly of microscopic floating organisms—the plants of the plankton. Principal among these plant organisms are the geometrically exquisite single-celled diatoms, housed in snowflakes of silica, and the whirling dinoflagellates, whose perpetual motion keeps them from sinking out of reach of the sunlight. These simple algae conduct the major portion of the photosynthesis that goes on in the ocean. They are the "grasses" of the sea. They synthesize carbohydrates, fats and proteins from carbon dioxide, sea water and certain nutrients. Under optimal conditions of light, temperature and nutrient supply, they may multiply to hundreds of thousands of cells per liter of water, clouding the water with a soupy "bloom"—yellow, green, red or brown, depending upon which species is dominant. At such times their prodigious capacity for multiplication becomes self-limiting, as they use up the supply of some critical nutrient or reduce the penetration of sunlight. More commonly the multiplication of the plant plankton is limited by the predation of the plankton animals that live upon it.

The smallest of these animals are single-celled protozoa which under the microscope look like tiny mollusks, encased in mineral shells of exotic design. The largest are wriggling crustaceans resembling small shrimp. Between these extremes of size is an endless variety of creatures, including the larval stages of many species of fish and of bottom-dwelling mollusks. Not all of these animals feed directly on the plants of the plankton; many of them prey on one another, the larger consuming the smaller. Finally the largest of the plankton animals are devoured by fishes, birds, seals and certain whales.

At each step in this food chain we must reckon with a considerable loss of organic matter. Only a small fraction of what an animal consumes goes to make up its substance. The rest is dissipated as energy in various forms, a large part of it being expended as mechanical energy in the creature's pursuit of its food. In general, 80 to 90 per cent of the organic matter is lost at each step. In the sea, as on the land, the hierarchy of predators forms a sharply narrowing pyramid. With 1,000 pounds of plant life at the base it shrinks to 100 pounds of animal plankton, then diminishes to 10 pounds of fish and is capped at its peak by only one pound of, say, sea lion.

Such calculation at once suggests that man might gain a great deal by short-cutting the food chain, perhaps going so far as to harvest the plant plankton directly. Except in a few regions, however, the plant plankton is too diffusely dispersed in the water. As a practical matter we need some animal to concentrate it for us. The ideal would be a plankton animal of appreciable size with a high rate of reproduction.

Now the whale makes exactly these requirements of its food supply. To achieve and maintain its huge bulk it must find its food close to the base of the pyramid. It is no accident that the most abundant species of whales, the baleen group, feed almost exclusively on a plankton animal. The baleen whales, among which is the blue or sulfur-bottom whale, the largest animal that has ever existed, are equipped with a mouth strainer, in the form of ingenious horny plates with fringed edges. When they scoop up their food in great mouthfuls of sea water, the strainer lets the plant plankton and small plankton animals escape but holds in the largest



FOOD RELATIONSHIPS among typical Antarctic ocean organisms are shown in this drawing. Plant plankton (*circle*) and the animal plankton which they nourish inhabit the sunlit upper layer. Swimming animals (nekton) include whales, porpoises and squid.

Whales feed on krill (*top center*), porpoises on krill and squid. Benthic animals (crabs and starfish) inhabit the bottom (benthos); they feed on animal remains from the upper layers. Organic material is ultimately swept upward by currents to renew the cycle.

of them—a bright red, shrimplike crustacean named *Euphausia superba* and known to whalers as krill or whale food.

Krill is an admirable answer to the whale's food needs. In the first place, the animal is a herbivore, bringing the whale to within one step of the plant plankton. The crustacean has efficient equipment for collecting the tiny plants that serve as its food: its hind limbs sweep currents of water toward a net of hairlike bristles under the forepart of its body, where the plants are entrapped and then swept into the mouth. In the second place, the animal is large enough (up to two and a half inches long) and abundant enough to feed the whale's gigantic appetite.

In the Antarctic waters, where many baleen whales feed, krill grows in enormous quantity. Since it takes a good many krill to make a meal for a whale, it is fortunate that they live close to the

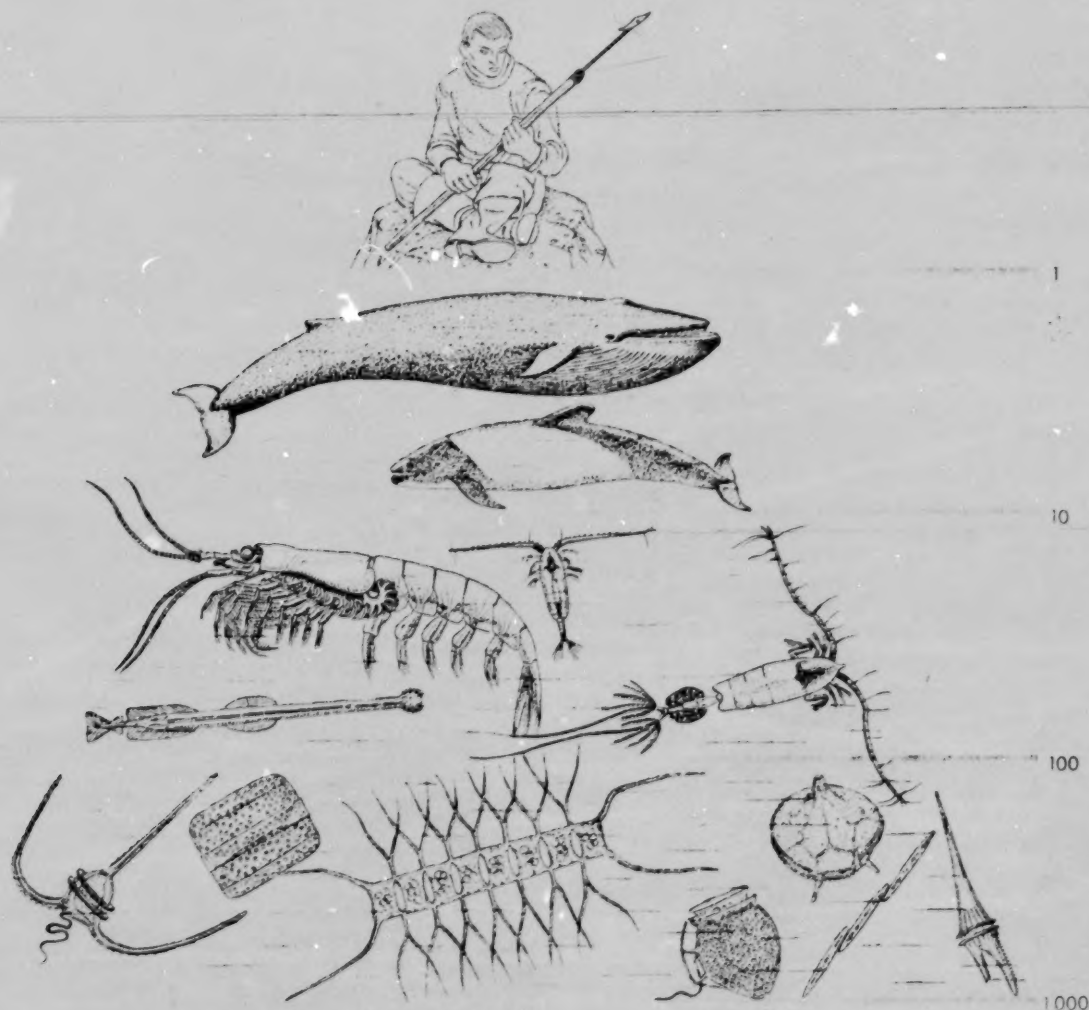
surface and are easy to catch. Cousins of this crustacean in other oceans are found only at depths of several hundred feet. But krill confine themselves to a thin zone within about 30 feet of the surface. They swarm in shoals and windrows from a few square yards to half an acre in size. Sometimes they are so densely packed that they give a reddish hue to the water. Aggregations of such swarms may extend for hundreds of square miles. The whales browse in their midst, singly and in herds, consuming vast numbers of them. Yet despite the fact that krill is the principal or exclusive food not only of whales but also of some species of seals, penguins, many other oceanic birds and hordes of fishes, the creature maintains a huge population, breeding larvae all summer long.

This plenteous animal surely deserves man's consideration as a possible food.

To see whether it could fill the bill, we must answer several questions. Would it supply our nutritional requirements? Would people want to eat it? Is it abundant enough to give significant relief to the world food shortage? I have looked into each of these matters.

In connection with an entirely different line of study I had occasion to do a biochemical assay of krill. The animal proved to be fairly rich in protein and fats. It can be calculated that a pound of krill will yield at least 460 calories—about the same as other shellfish. The eyes of krill are unusually rich in vitamin A, a feature which might have by-product interest if the animal were fished on a large scale.

How palatable is krill? I happen to know of at least one occasion when people ate some krill (taking them from



SIMPLIFIED PYRAMID of Antarctic life begins with plant plankton (bottom) and ends with man. Energy loss at each step is about

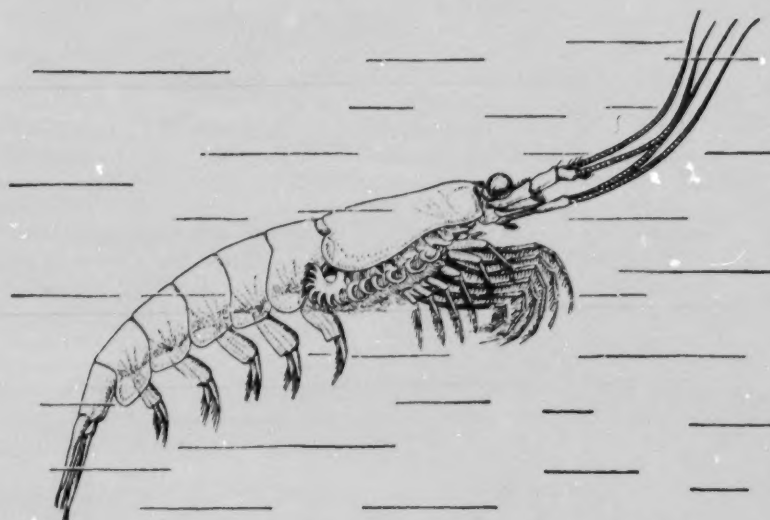
90 per cent; 1,000 pounds of plant plankton produce 100 pounds of animal plankton, 10 pounds of whale and one pound of man.

the freezer in my laboratory under the mistaken impression that they were shrimps). The consumers naturally were most uncommunicative, but I have reason to believe that the crustaceans were eaten with relish, and no untoward after-effects were experienced. Their removal from the deep freezer can be taken also as a tribute to the appetizing appearance of these bright red animals.

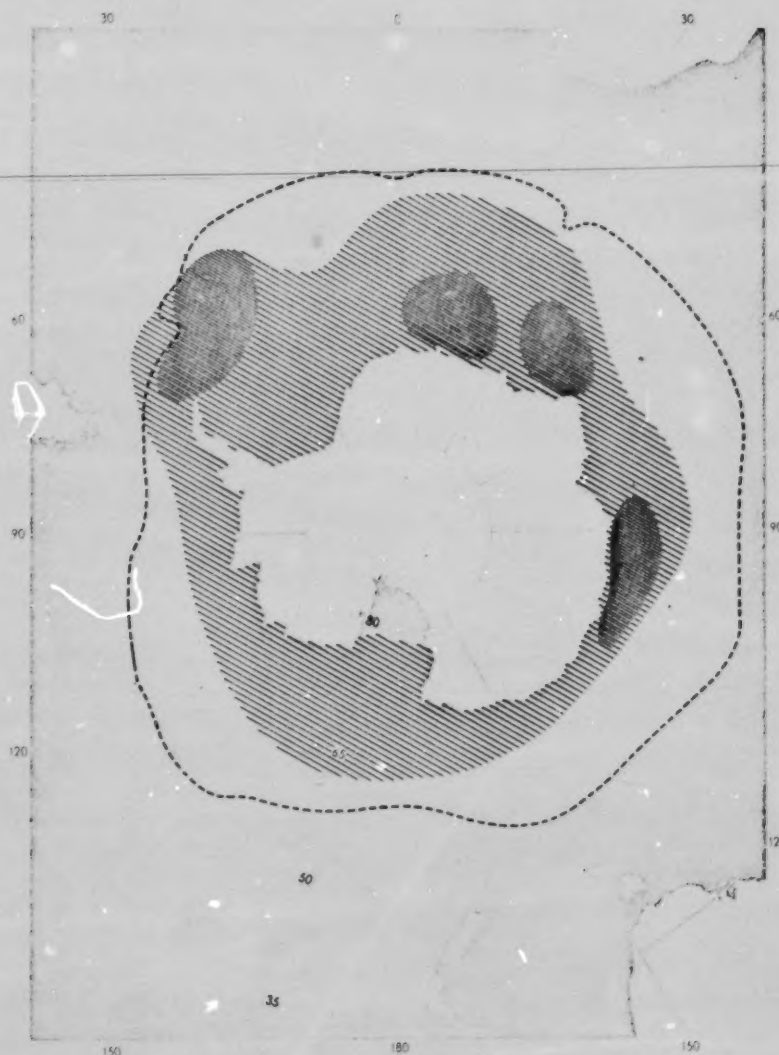
As to their abundance in the sea, we must take an indirect census. Let us consult the whale, estimating its krill consumption from its energy requirements. I estimate, with advice from authorities on fluid dynamics, that an average-sized adult blue whale, weighing some 90 tons, develops about 10 horsepower when it swims at the moderate pace of four knots. (Whales have been observed to reach 12 knots easily.) Assuming that the muscles propelling the animal are about 20 per cent efficient in converting food into power, we can calculate that a blue whale needs about 780,000 calories per day for propulsion. To this we must add an energy allowance for maintenance of its body temperature and processes such as digestion and respiration. A rough estimate based on the whale's surface area puts this figure at 230,000 calories per day. The total so far, then, comes to more than a million calories per day. At about 460 calories per pound of krill, this means an average daily consumption of about 2,200 pounds—more than a ton of food.

We are not yet finished, however. During its growth period (i.e., the first five years of its life) a blue whale gains at the average rate of 90 pounds per day. So a growing whale needs another 800 to 800 pounds of krill per day, raising the total to a ton and a half. Now we have to double this figure to arrive at the actual daily consumption, because we have reason to believe the blue whale feeds only half the year. For the winter it leaves its feeding grounds in the Antarctic and migrates north to more temperate waters. Whale authorities believe that the whale does not feed to any appreciable extent outside the krill range in the Antarctic Ocean but lives through the half year on stored energy. The grand total of a growing blue whale's food intake while it feeds is, then, about three tons of krill per day!

Now we are in a position to estimate how much krill the whale population as a whole may consume. To judge the highest potential we have to go back to 1910, before whalers began to cut down the whale herds in the Antarctic. The population at that time is estimated to have been half a million. Half a mil-



LOBSTER KRILL (*Euphausia superba*) is the largest of several related species consumed in enormous quantities by whales. Its forelimbs trap the plant plankton on which it feeds.



DISTRIBUTION OF KRILL around Antarctica in summer is shown by shading; heavier shading denotes denser concentrations. The broken line surrounds the "Antarctic convergence," within which upwelling nutrients support a luxuriant growth of plant plankton.

lion whales consuming three tons of krill per day for six months gives a total of 270 million tons of krill per year. Since it is highly unlikely that whales harvest more than 20 per cent of the krill in any given area, the total annual production of krill must have been at least 1,350 million tons. On the 3.5 million square miles of feeding grounds this averages to about 1,000 pounds per acre.

At that rate the krill crop in the ocean bests the animal yield on land, for rich pasture land gives about 700 pounds of cattle and sheep per year. The comparison is apt, because these animals, like krill, are herbivorous, converting plants to meat. Krill is, by this token, a far more

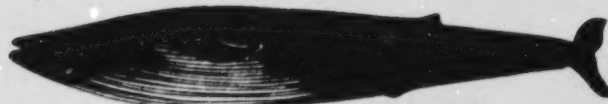
efficient producer of food than carnivorous fishes, which under cultivation in ponds yield only 100 to 250 pounds per acre per year.

The whale's example shows that we can reap vastly increased returns from the biological economy of the oceans. The 270 million tons of krill on which the Antarctic whales fed in their heyday would be more than enough to supply the annual requirements of the entire U. S. population.

There are growing indications that krill may be a timely subject. Some 250 ships and 16,000 men—the largest whaling fleet in history—are now operating in the Antarctic Ocean. They depend main-

ly on the fin whale. If and when this species follows the blue and humpback whales into near-extinction, whalers may find it worth while to turn their attention to krill. My own calculations, based on operating costs of ships, processing costs and a likely market price for krill, indicate that even today krill-trawling might be more profitable than whaling.

We ought to begin a scientific exploration of this promising possibility in the Antarctic Ocean. A pilot project in krill-fishing would enable scientists, engineers and businessmen to join hands in a project which would not only advance knowledge but might also develop a valuable source of food.



WHALES, PLANKTON, AND MAN - Three Level Guide

Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those that you believe say what the author actually said or paraphrased in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference. Also, be ready to explain what is inaccurate about the statements that you do not check.

- _____ The whale feeds directly upon the plants of the sea.
- _____ The single-celled diatoms conduct the major portion of the photosynthesis that goes on in the oceans.
- _____ In each step of a food chain between 80 and 90% of the organic matter and hence the energy is lost.
- _____ Baleen whales depend upon medium and large sized fish for their food.
- _____ Shrimplike krill are plant plankton eaters that bring the baleen whale to within one step of the producers.
- _____ To serve as a food for man, krill would have to:
(1) supply our nutritional requirements (2) be tasty
(3) be abundant.
- _____ Adult whales need about one million calories per day.
- _____ Adult whales need to eat about 600 to 800 pounds of krill per day.
- _____ The two hundred fifty ships and 16,000 men who make up the largest whaling fleet in history might find it more profitable to fish for krill.

Directions: Now compare your answers with those of others in your group. If there are many differences, find the page and paragraph that support your answer and write them next to the statement in question. When you finish your discussion, go on to the next level.

Level II. Directions: The statements below may or may not be true. Check each statement you believe is a generalization the author himself draws based on the information he gives in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference.

- _____ The plant plankton numbers are maintained in check by several interrelated factors.
- _____ Whales and man face very different problems in obtaining sufficient food.
- _____ A food suitable for maintaining baleen whales would have to be very numerous.
- _____ It is time to re-evaluate the economics of whaling and krill fishing.
- _____ Efficient production can yield 100 to 250 pounds per acre per year.
- _____ Since krill feeds directly upon plant plankton, its use as a food would be energy efficient.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to next level.

Level III. Directions: Read each statement below, relating the details and author's interpretations drawn from the selection to ideas and experiences you've had in reference to this topic. In column A, check the statements which Pequegnat would have agreed with. In column B, check the statements you agree with.

- | A | B | |
|-------|-------|--|
| _____ | _____ | The food resources in the sea offer a real challenge to mankind and a possible source of additional protein. |
| _____ | _____ | If man is to survive in ever increasing numbers, we will have to concentrate on food species closer to the beginning of the world's food chains. |
| _____ | _____ | It is possible to determine the abundance of animals by analyzing the stomachs of predators on these animals. |

_____ New and creative approaches to our utilization
_____ of ocean resources are needed.

_____ Krill fills the bill.

Directions: Again, compare your answers with your group.
Where there are differences, try to resolve
them.

TEACHER BACKGROUND - One Step Further.....and More One Step Further.....

Authors, editors and publishers spend a great deal of time, effort, and money to produce the graphics which accompany printed works. The purpose of these graphics is, of course, to clarify and elaborate on the materials of the text. Unfortunately, many students do not use these aids to understanding. This exercise is designed to introduce the student to the utility of the figures included in "Whales, Plankton, and Man".

Plan to allow time for a discussion of the graphics and to provide the correct answers upon completion of this exercise.

KEY

Food Relationships

1. The "benthos" are the bottom dwelling animals. This is shown in the scale on the right side of the figure. To add to the confusion, the caption for the article refers to the "benthos" as the bottom.
2. Organic matter is recycled from the bottom by upward sweeping currents.
3. Many food chains are possible: For example,

plankton	→	krill	→	whale
plankton	→	krill	→	squid
plankton	→	squid	→	crab

Simplified Pyramid

1. The numbers at the right hand edge of the figure signify that energy loss at each step is about 90% and that 1,000 pounds of plant plankton produce 100 pounds of animal plankton, 10 pounds of whale and one pound of man.
2. The lowest level, the phytoplankton, has the greatest number of organisms while the highest level, man, has the least number of organisms. This figure represents a pyramid of numbers.
3. To produce a 100 pound man, 100,000 pounds of plant plankton would be required.

Lobster Krill

1. The forelimbs of Euphausia superba are especially adapted to trapping plant plankton by virtue of the large number of very fine hairs that form a net which is swept through the water.

Distribution of Krill

1. Upwelling of nutrient rich bottom waters occurs in the area surrounded by the broken line. The nutrients provide the "fertilizer" necessary for plant plankton growth.
2. The areas which would be of special interest to the captain of the M. V. Krill Killer would be those four shown by the heaviest shading. The krill is most numerous in these areas.

One More Step Further

1. 780,000 propulsion + 230,000 body functions = 1,010,000
total calories needed
2. 1,010,000 total calories needed $\div$ 460 calories = 2196
pound krill pounds of krill
needed per day
3. 2196 pounds of krill + 800 pounds of krill = 2996 total intake
per day needed by per day for growth
the whale
4. 2996 total intake $\times$ 2 (the whale only = 5992 grand total of
feeds for half krill per day.
the year)

KEY WORDS

adapted
 benthos
 calculations
 caloric
 calories
 food chain
 graphics
 krill
 nekton
 organic

plankton
propulsion
recycled
relative number

ONE STEP FURTHER

Willis E. Pequegnat, the author of "Whales, Plankton, and Man", provides us with several illustrations. These figures are designed to help the reader to better understand the points made in the text. Use the graphics in "Whales, Plankton, and Man" to answer the following questions.

Food Relationships

1. "Plankton" are the drifting animals while "nekton" are the swimmers. What are the "benthos"?
2. How does organic matter get recycled from the bottom?
3. Construct two possible food chains using the information in the figure.

Simplified Pyramid

1. What do the numbers at the right hand edge of the figure signify?
2. The figure tells us something about the relative number of organisms at each level. Which level has the greatest number of organisms: Which has the least?
3. How many pounds of plant plankton would be required to produce a one hundred pound man?

Lobster Krill

1. How are the forelimbs of Euphausia superba especially suited (adapted) to trapping plant plankton?

Distribution of Krill

1. What happens within the area surrounded by the broken line? How does this help plant plankton growth?
2. As captain of the M. V. Krill Killer, how are the areas you would be especially interested in marked on the figure?

More One Step Further

The calculations the author used to determine the caloric needs and food intake of the whale are a bit overwhelming. Fill in the blanks below to streamline the arguments.

Number of calories per day for:

1. _____ propulsion + _____ body functions = _____ total
calories needed
2. _____ total calories $\div$ _____ calories = _____ pounds of
needed pound krill krill needed
per day
3. _____ pounds of krill + 800 pounds of krill = _____ total
per day needed per day for growth intake
by the whale
4. _____ total intake x 2 (the whale only = _____ grand total
feeds for half of krill per
the year) day.

BIOLOGICAL FACTORS:

Algae - The Producers

TEACHER BACKGROUND - Sea Forest

The visible marine algae so ingratically called "seaweeds" are often overlooked as uninteresting and insignificant. These plants display a great variety of form, color and size and play a large economic role in modern society. "Sea Forest" gives your students an introduction to these plants. The best place to learn about seaweeds is at the beach itself. "Sea Forest" can serve as background material for a trip. If it is not possible to visit the shore, these activities can stand on their own. Additional information about seaweeds and seaweed identification keys may be found in the reference materials listed in this section.

Duplicate the text materials. One set is recommended per student. This activity lends itself well to individual completion as an in-class assignment or as homework. You might elect to have your students meet in small groups to discuss their answers before you conduct a general discussion in which you provide answers. Use the technique that best suits the needs and abilities of your particular class. A crossword puzzle has been included to reinforce the new vocabulary introduced in this section. Recognize the new terminology introduced and use it whenever possible in your discussion with your classes. While the scientific names of the plants illustrated are given, there is no real attempt to deal with the systematics of seaweed classification. Identification and systematics are best left to be tackled with seaweed samples in hand.

KEY

1. Land and marine plants face rather different stresses. Land plants are limited by water availability and by nutrient availability. They also must face problems dealing with transporting the water and nutrients to all parts of the plant. Marine plants are surrounded by water complete with nutrients. As a result few marine plants have evolved elaborate transport systems. Marine plants are also largely free from the problems of gravity. The water supports the plant so they seldom have woody tissues like those required by land plants for support. The answer to this question relies on previous knowledge gained by the student since the answer is not to be found directly in the text.

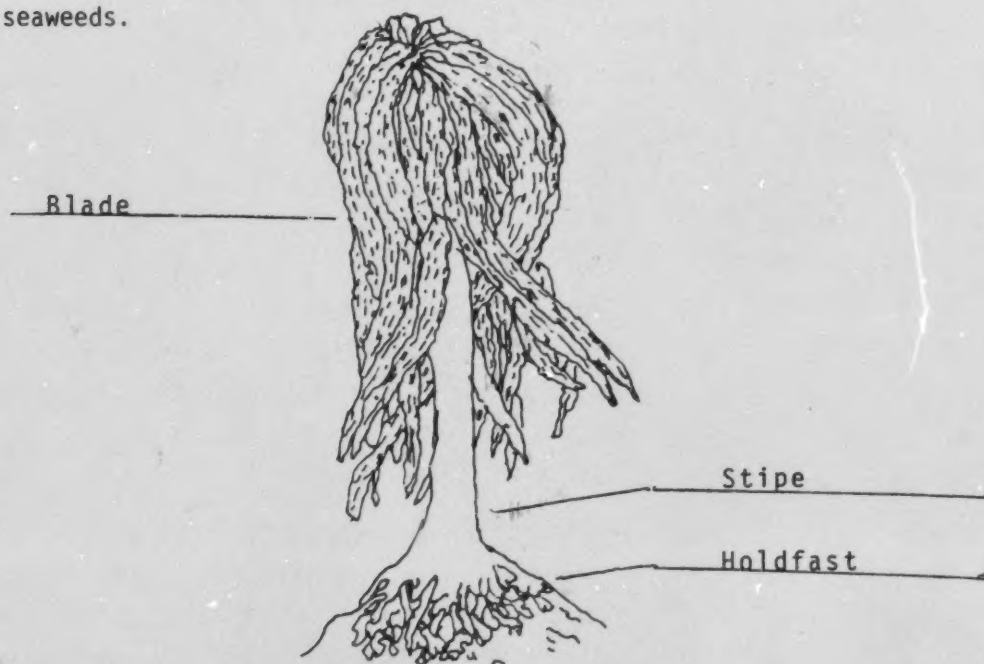
2. At this stage most students will probably say "no" they have not eaten seaweed. This question is rhetorical and is used primarily as an introduction to a subsequent section on algae derivatives.
3. Your students should be able to imagine many possible problems including: smog, over harvesting of kelp, solid waste production, etc. This question is designed to help your students to learn to anticipate the next section as they read.
4. Four historical uses for seaweed mentioned in the text are: (a) food; (b) soda ash; (c) potash (fertilizer); and (d) iodine.
5. Three major products derived from kelp (and other seaweeds) are:
 - (a) algin
 - (b) agar
 - (c) carrageenan

Unless your students read the ingredient labels on food, they probably have never heard of these products. This question makes them write the unfamiliar words as an aid to incorporating them into their vocabulary.

6. The answers will vary but should come from the lists included in the text.
7. The three groups of seaweeds mentioned are:
 - (a) green seaweeds; (b) brown seaweeds; (c) red seaweeds.

The blue green algae comprise another, but less common, group of seaweeds.

8.



9. The advantage to variation lies in the fact that if environmental conditions change, the species will be more likely to have members that can thrive or survive under these new conditions if there is variation in the population. Lack of variation means that if the environmental conditions are such that they will kill one individual, they will kill all of the individuals. Variation is a benefit to the species; not to the individual per se.
10. The variations in environmental conditions that exist because of the changing levels of the tides are the primary cause of the parallel bands of seaweed observed on a rocky shore.
11. Many environmental conditions vary as one moves up or down the intertidal beach: temperature, exposure to drying, exposure to wave action, submergence, exposure to predators, etc. This question may serve as a springboard for a general discussion of the environmental factors facing intertidal organisms.

KEY - CROSSWORD PUZZLE (see following key words)

KEY WORDS

agar
algae
algin
blade
botanists
brown algae
carrageenan
chlorophyll
chlorophyta
diatoms
dinoflagellates
fermentation
gel
green algae
habitats
holdfast
intertidal zone

iodine
parallel
phaeophyta
photosynthesis
potash
red algae
rhodophyta
seaweeds
soda ash
spores
stipe
thallophytes
tidal cycle
zonation

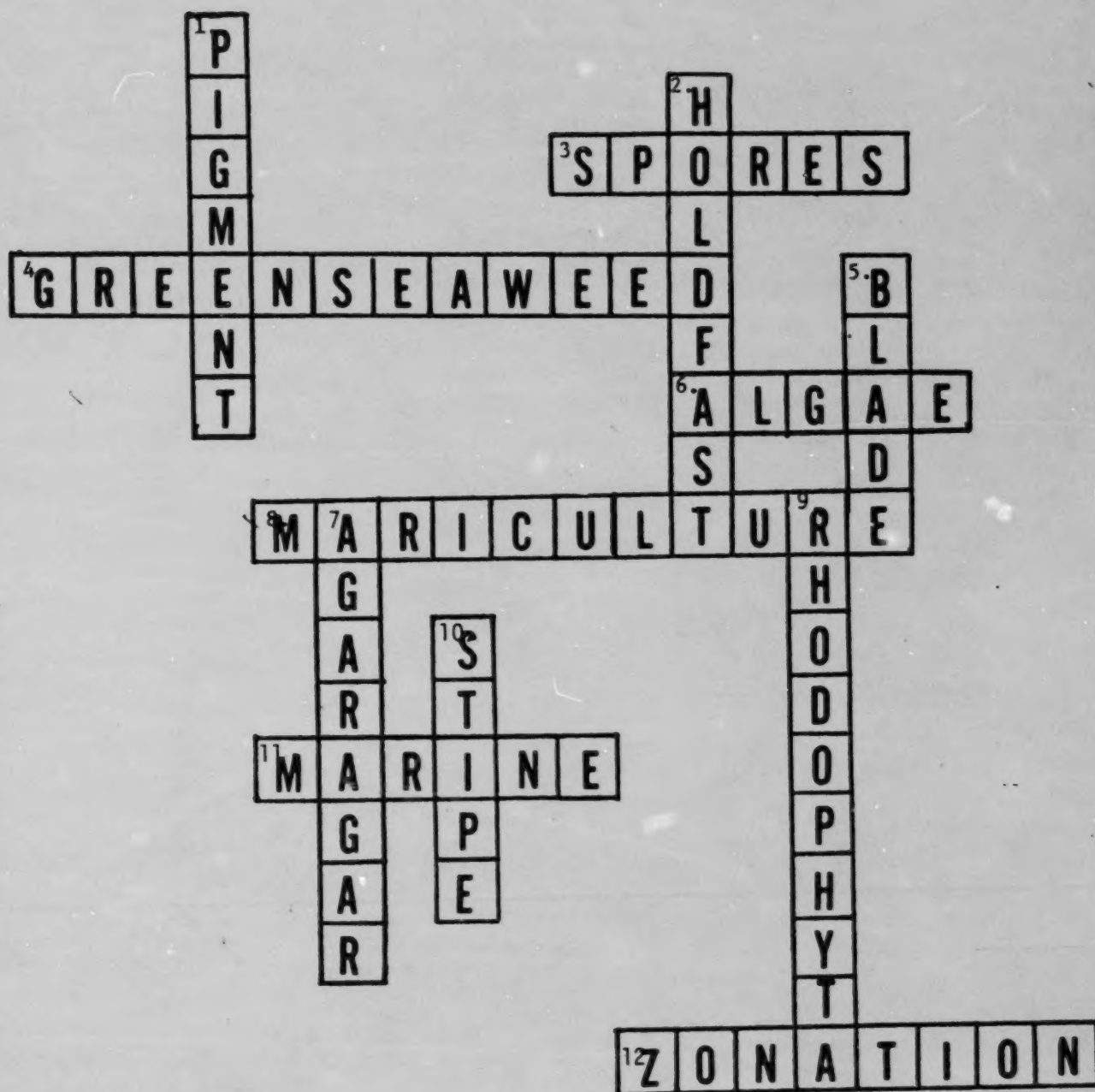
Reference Materials:

Dawson, E. Yale: Seashore Plants (University of California Press; 1966).

Guberlet, Muriel Lewin: Seaweeds at Ebb Tide (University of Washington Press; 1956).

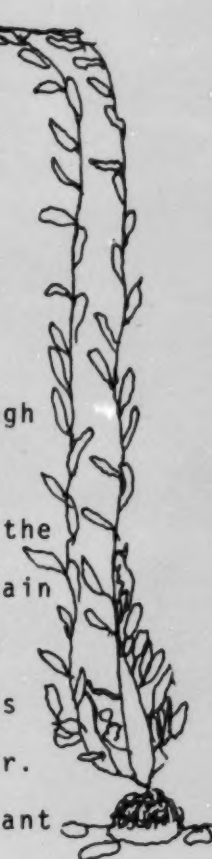
Kozloff, Eugene N.: Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago (University of Washington Press; 1973).

Scagel, R. F.: Guide to Common Seaweeds of British Columbia (British Columbia Provincial Museum, Victoria. 1967).

Solution to Crossword Puzzle

SEA FOREST

Where are the trees of the sea? Where are the forests? Most of the plants that grow in the sea are microscopic diatoms and dinoflagelates. The larger, more conspicuous, sea plants are very different from land trees. These plants, called seaweeds, belong to the group of plants known as algae. Like many other plants, seaweeds capture energy from the sun and through the process of photosynthesis use this energy to make more algae. This highly complicated process requires the green pigment chlorophyll. Although all seaweeds contain chlorophyll, they are not all green. Botanists, those scientists that study plants, group the different kinds of algae into groups partly on the basis of their color. In spite of their name, seaweeds have long been important to man. In the future, we can look for their importance to grow.



1. LAND PLANTS and marine plants face different environmental conditions. What are two factors that often limit where land plants can grow that are usually not a problem for marine plants?

A Little History

The earliest use of seaweed was as a food. For centuries the peoples of the Far East have harvested and cultivated seaweeds (mariculture) as a food source. Today, certain species of seaweed bring very high prices as relished specialty foods in Japan and other Asian nations. While these seaweeds have been introduced into the American market,

they have not gained wide acceptance. Perhaps a change of name might be beneficial. People might be more willing to eat "nori" than "seaweed". Because the seaweeds concentrate minerals and vitamins, they are a valuable food. Seaweeds are also eaten in South America and to a limited extent in some of the European countries. Although the oldest use for seaweed is as food, it is no longer the only or even the largest use.

2. Have you ever eaten seaweed? If so, when and where?
During the seventeenth century, French peasants began to manufacture soda ash from seaweeds known as brown rockweeds and oarweeds.



Fucus sp.



Laminaria sp.

The manufacturing process was simple but yielded substantial quantities of soda needed by glass makers and pottery glazers. The algae were collected by hand at low tide or after storms. As in most cottage industries, the whole family was involved. The young men were in charge of collecting

the seaweed while the women, children and older men burned the seaweed in kilns.

3. What environmental problems might be caused by the manufacture of soda ash using this process?

It wasn't long before people began to take a closer look at the burning process. The burned seaweed was discovered to be a source of potash, an important fertilizer. Iodine was also discovered to be present in seaweed and techniques were developed to remove the iodine before the soda and potash were extracted. The iodine played a very important role in medicine. People also noticed the dense clouds of smoke coming from the kilns. As early as 1769, in France, complaints from neighbors stated that the fumes from the kilns damaged the fisheries and adjacent orchards.

Other sources of the end products and new technologies have replaced the burning process with a fermentation process that yields a greater variety of products. The Soviet Union is now the only major producer of iodine from seaweeds. It is difficult to predict with certainty but as land-based supplies of the materials once provided by seaweeds decrease, seaweeds may again play an important role in the economy of many maritime nations.

4. What were four historical uses for seaweeds?

The importance of seaweed in today's economy comes from the yield of products which were once discarded in the

extraction of iodine, soda, and potash. Today, boat mounted "kelp mowers" harvest kelp from the surface down to a depth of about four or five feet. The kelp moves onto a conveyor belt and into a chopper where whirling knives cut it into six inch lengths. The kelp is loaded into a barge and taken to shoreside factories. Using these boats, crews of from six to nine men can harvest up to 50 tons per hour. The kelp is used in the manufacture of algin, agar, and carrageenan. Yippee.

5. What are the three major products derived from kelp?

- a. _____
- b. _____
- c. _____

What are these products? Algin powder has the interesting property of absorbing large quantities of water. One teaspoonful of algin dissolved in a quart of water will make the water so thick that it can hardly be poured. This is handy for lots of things. A teaspoonful of algin added to a gallon of ice cream prevents the water from forming coarse ice crystals in the ice cream. It also helps prevent the cupcake icing from sticking to the cellophane wrapper of your favorite sweet treat. Algin suspends penicillin and other antibiotics in solution so that they may be uniformly administered. It suspends the abrasives in autopolish and the pigment in paints. As can be seen from the list which follows, the uses of algin are incredible.

Miscellaneous food products

Bakery icings and meringues
Salad dressings
Frozen foods
Fountain syrups
Orange concentrates
Candy
Puddings

Dairy products

Ice cream
Dry ice cream mix
Sherbet
Chocolate milk
Chocolate toddy
Sterilized cream
Cheese

Miscellaneous products

Paints
Ceramic glazes
Porcelain ware
Leather finishes
Auto polishes
Welding rod coatings
Boiler compounds
Battery plate separators
Wallboard joint cement
Beet sugar processing
Wax emulsions

Adhesives

Wall board
Paper bags
Shipping containers
Gummed tape & decals

Textile products

Textile print pastes
Plastic laundry starch
Size compounds for cotton & rayon

Rubber

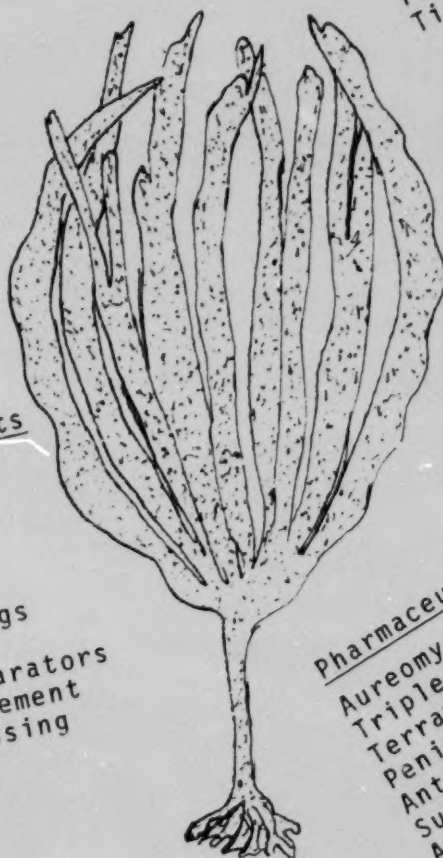
Natural & synthetic
Latex creaming
Automobile carpeting
Electrical insulation
Babies' rubber pants
Rubber coating
Foam coating
Tires

Paper products

Food packages
Pharmaceutical soap
Milk containers
Butter cartons
Frozen food packages
Insulation board
Food wrappers
Greaseproof paper
Acoustical tile

Pharmaceutical products

Aureomycin tablets
Triple Sulfa tablets
Terramycin suspensions
Penicillin tablets
Anti-acid tablets
Sulfa suspensions
Aspirin compound tablets
Calamine lotion
Hemostatic powders
Bulking lotions
Toothpaste
Dental impression compounds
Orthopedic impression
Surgical jellies
Suppositories
Mineral oil emulsions
Rubbing ointment



Agar is a gel, a jelly-like substance, usually extracted from seaweeds by boiling. Agar is very important in microbiological laboratory studies where it provides a "medium" for the growth of micro-organisms. Agar is non-toxic and is widely used in the canning of meat and fish. It is found in some other canned foods and cereals as well. Agar is also used in many of the same ways as algin and carrageenan.

Carrageenan is used extensively in the production of many products. Because of its non-toxic properties, it is used in many of the same branches of industry as algin. The list on the next page shows how widespread the use of carrageenan is today. It is safe to say that everyone in this country has either eaten seaweed or used products manufactured with seaweed derivatives. These "weeds" are important contributors to the quality of life.

6. What are three ways you have used: algin, agar, and carrageenan?

<u>algin</u>	<u>agar</u>	<u>carrageenan</u>
a)	a)	a)
b)	b)	b)
c)	c)	c)

Types of Seaweeds

Let's take a look at the plants that provide us with so many products and which played an important role in the development of our technological society. For convenience, the marine algae that are large enough to

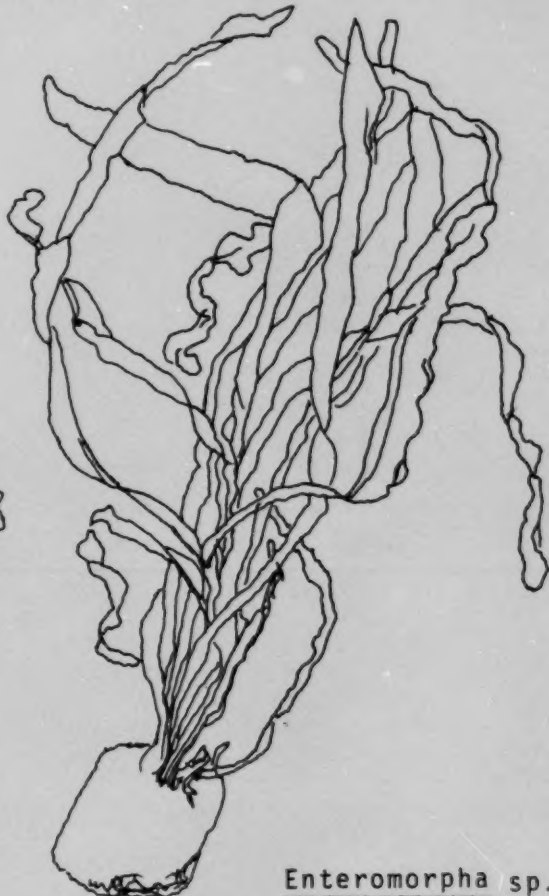
pick up are called seaweed. This size distinction eliminates the many kinds of microscopic algae from the category. Botanists place seaweeds into three groups: green seaweeds, brown seaweeds and red seaweeds. These three groups differ more than by color.

7. What are the three groups of seaweeds?

The green seaweeds or chlorophyta includes about 7000 different species. Only a few of these are found in the sea. Some of them are several feet long. The sea lettuce, Ulva sps., is the most widely known example of a marine green seaweed. The green seaweeds are not extensively harvested by man although some varieties are used as food.



Ulva lactuca

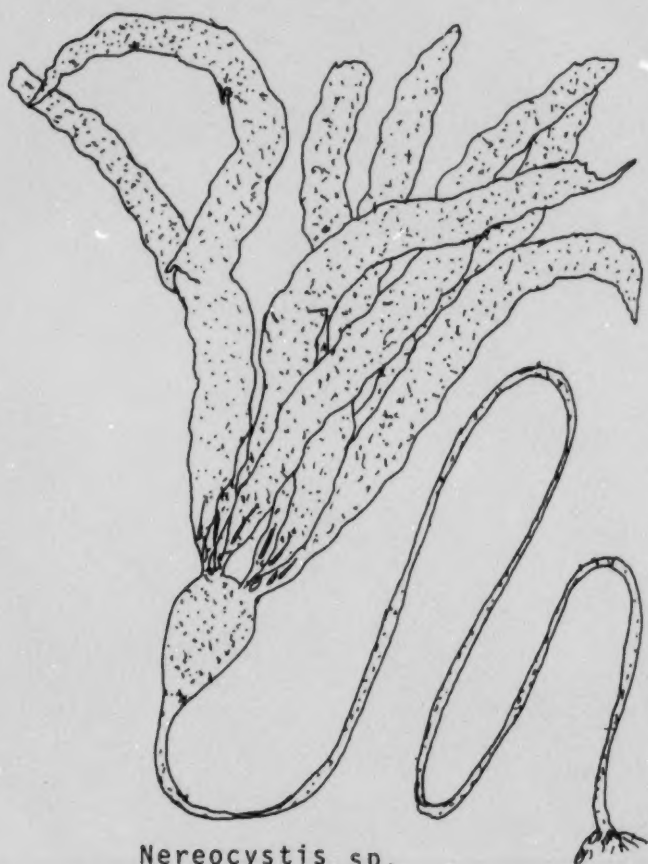


Enteromorpha sp.

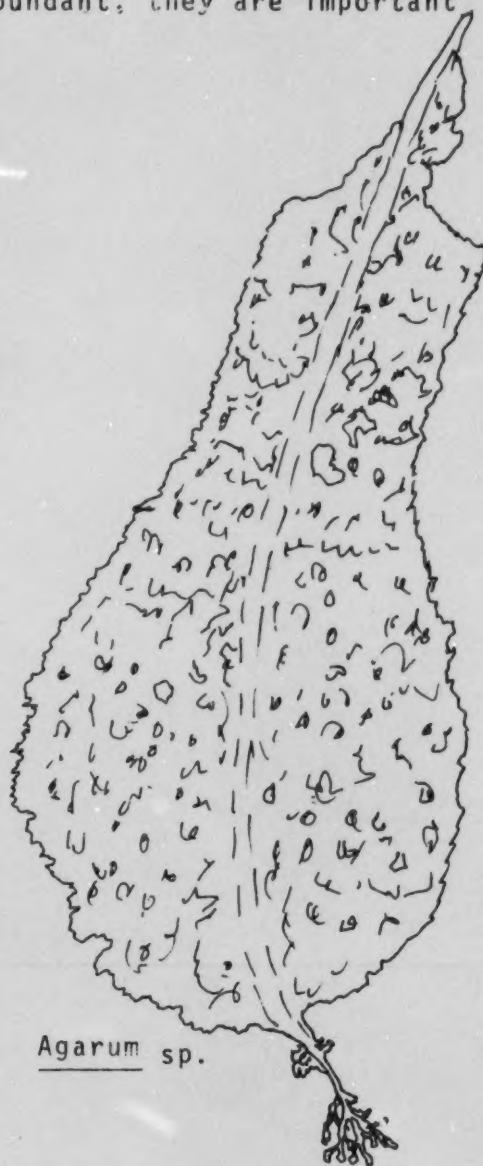
MAJOR ALGAL GUM APPLICATIONS IN THE FOOD INDUSTRY

	<u>Agar</u>	<u>Carrageenan</u>	<u>Alginates</u>
<u>Dairy</u>			
Ice cream stabilizer	x	x	x
Ice pops and water ices	x	x	x
Chocolate milk drink		x	x
Flavored milk drinks		x	x
Puddings	x	x	x
Eggnog mix		x	
Cottage cheese		x	x
Cream cheese	x	x	x
Cheese spread		x	x
Whipped cream		x	x
Yogurt	x	x	
<u>Beverages</u>			
Soft drinks		x	x
Fruit juices		x	x
Beer foam stabilizer		x	x
Fining wines etc.	x	x	x
<u>Bakery</u>			
Bread doughs	x	x	
Cake batters	x	x	
Pie fillings	x	x	x
Bakery jellies	x	x	x
Doughnut glaze	x	x	x
Meringues	x	x	x
Cookies	x		
Cake fillings & toppings	x	x	x
Frozen pie fillings		x	
<u>Confectionery</u>			
Candy gels	x		x
Caramels, nougats		x	
Marshmallows	x		
<u>Dressings, sauces</u>			
Salad dressing		x	x
Syrups, toppings		x	x
Relish		x	x
Mustard, cocktail sauces, catcup		x	x
<u>Meat, fish</u>			
Sausage casing	x		x
Fish preservation			x
Canned fish, meat etc.	x	x	x
Coated jellied meat		x	x
Sausage ingredient		x	
Preservative meat coat	x	x	x
Synthetic meat fibres		x	x
<u>Miscellaneous</u>			
Jams, preserves	x	x	x
Prepared cereals	x		
Processed baby food		x	
Soups	x	x	x
Fountain toppings		x	x

The brown seaweeds or phaeophyta are common along the ocean coasts especially in the colder seas. The largest of the algae, the brown algae grow attached to rocks from the high tide line to depths of 75 to 100 feet. The giant kelp may grow to a length of over a hundred feet. Because the brown algae are widespread and abundant, they are important economically.



Nereocystis sp.



Agarum sp.

Red seaweeds or rhodophyta do not get as big as brown seaweeds. The red algae are almost entirely marine. Red seaweeds grow on rocks from the tidal zones or down to the maximum depth of light penetration. Most of these seaweeds can be recognized by their red, reddish-purple or reddish-brown color. In spite of their smaller size, these seaweeds are about as economically important as the brown seaweeds.



Gigartina exasperata



Constantinea simplex



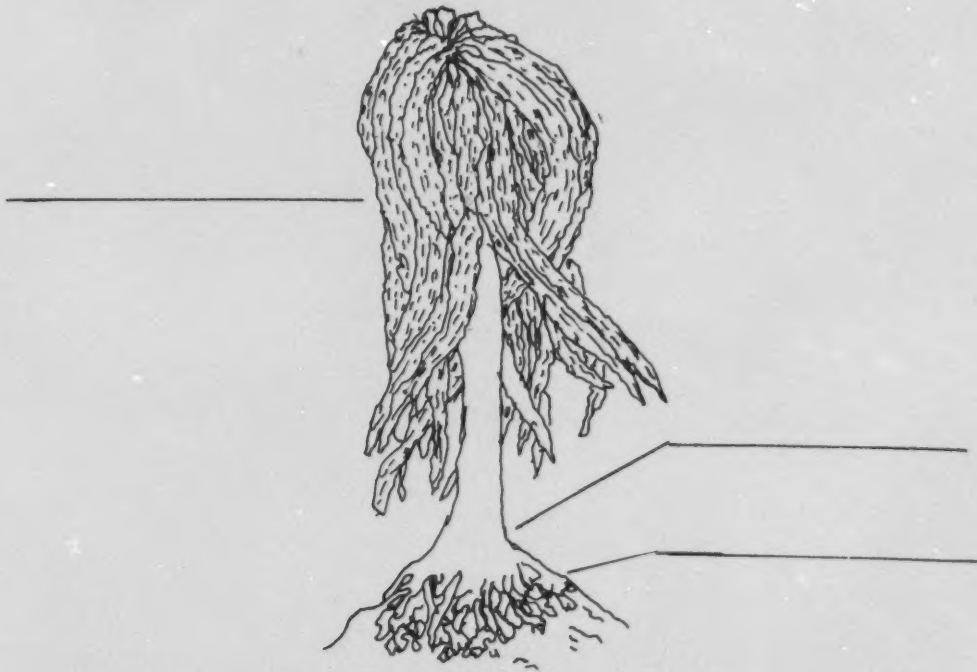
Corallina sp.

The Plant

Algae are relatively simple plants that never form true roots, stems or leaves. Scientists group the algae along with bacteria and fungi in the subkingdom of plants known as the Thallophytes. Seaweeds may be attached or free floating. Those that are attached have a thickened root-like extension called a holdfast. Unlike true roots, the holdfast doesn't serve to nourish the plant and seaweeds broken off above the holdfast will usually keep on growing.

Some seaweeds have a stem-like area called a stipe and a leaf-like area called the blade. It is not always easy to tell where the stipe ends and the blade begins.

8. Label the sea palm shown below:



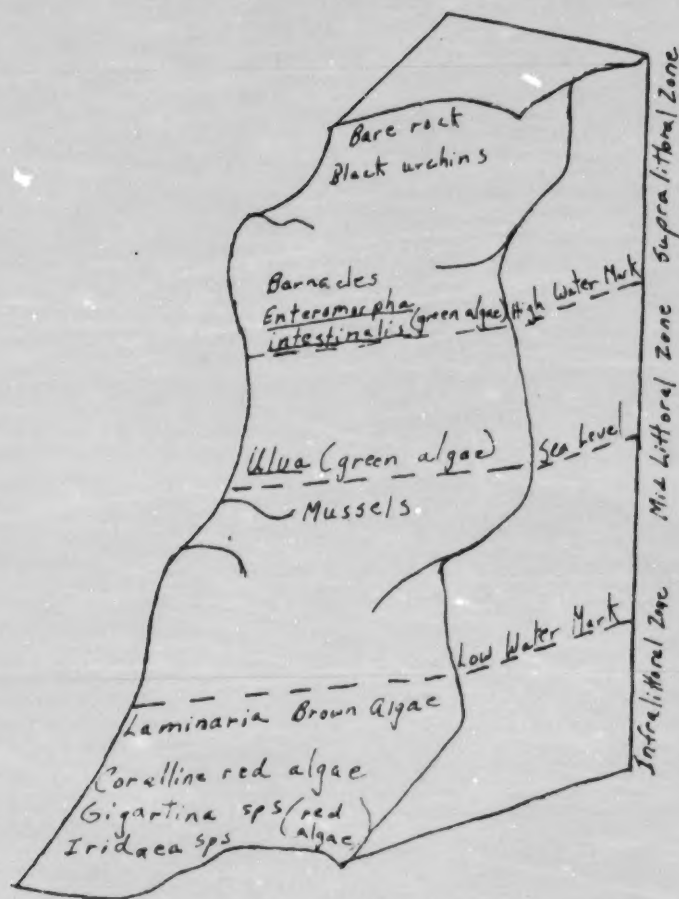
Algae never form flowers or seeds. The most common form of reproduction involves the formation of tiny spores. The spores either float or swim away and form a new plant. Some of the red and brown algae reproduce by breaking apart. Each section of the plant body may become a new individual. In this case, the new plants are carbon copies of the original.

9. Algae can also reproduce sexually. Sexual reproduction results in offspring that are not exact copies of the original. What is the advantage to the species in having variation among the individual members?

Relationships

Seaweeds play an important role in coastal areas. They provide homes (niches) for many small animals as well as for different species of algae. Close examination of seaweed will reveal small crabs, fish and snails that look very much like the seaweed. The seaweeds also assist in reducing the full force of storm waves. Because of their important roles as provider of habitat and wave breaker, it is important that seaweeds are not destroyed by man's harvesting or carelessness.

Each seaweed has its own special requirements necessary for life. The beach of the intertidal zone provides many different habitats due to the changing tides. As a result of the different habitats, we observe a definite zonation of seaweeds when we observe a rocky coast. The variations in the environmental conditions that exist cause parallel bands of different types of seaweeds. While these parallel bands may be only a few meters or less wide, they may stretch for hundreds of kilometers along a coast line. As one might expect, the parallel bands of plants support different kinds of animals.

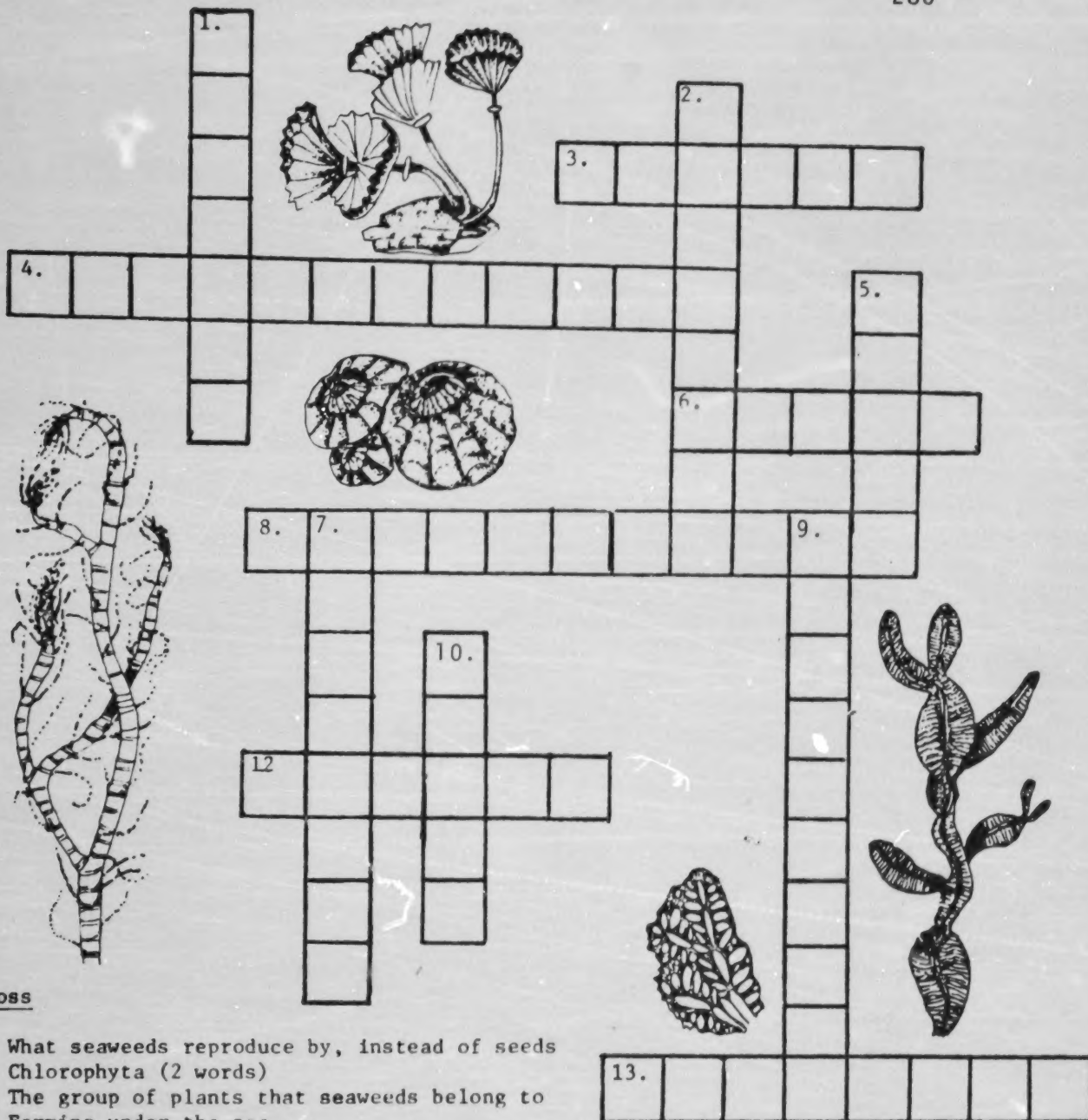


10. What causes the parallel bands of seaweed that are observed on a rocky shore?

The environmental factor chiefly responsible for the zonation we see is the tidal cycle. The organisms found highest on the beach are those that are best adapted to withstand long periods of exposure to drying conditions. Organisms found lowest on the beach are those able to withstand nearly constant submergence. Within the intertidal area many forms of life survive and multiply in the turbulence of the continuously pounding surf. Seaweeds are the

backbone of the intertidal ecosystem. Without them, the sea beach would be a very different place.

11. What are three environmental conditions that vary as one moves up or down the intertidal beach?



Across

3. What seaweeds reproduce by, instead of seeds
4. Chlorophyta (2 words)
6. The group of plants that seaweeds belong to
8. Farming under the sea
12. Sea-dwelling
13. The arrangement of seaweeds in zones on the seashore



Down

1. Coloring
2. "Root" of a seaweed
5. "Leaf" of a seaweed
7. Used commercially
9. Red seaweeds
10. "Stem" of a seaweed

This Crossword puzzle originally appeared in: "Ocean Going Plants" a Florida 4-H Marine Program publication.

TEACHER BACKGROUND - Keys to the Kingdom

Keys are an important tool in the identification of unfamiliar organisms. In this activity your students will have an opportunity to examine two keys and to construct a key of their own. It is important to emphasize that most keys are restricted to the organisms found in a particular area. Local keys are useful because the restricted number of organisms treated reduces the number of very fine distinctions which would have to be made if large numbers or many similar organisms were included on a single key. Since keys are an artificial construct, different keys can be designed to "key out" the same group of organisms. The most common type of key and the one introduced in this activity is the dichotomous key, a key with two choices at every level. Ideally, the choices are simple "yes" and "no" items ("the item is red" vs "the item is not red") and the discriminating features are things which can be verified by direct observation ("the item is $\frac{1}{2}$ inch or longer in length" vs. "the item is less than $\frac{1}{2}$ inch in length"). The alternatives should be quantifiable ($\frac{1}{2}$ inch or longer rather than "big" or "small"). A good way to introduce the concept of dichotomous keys is to construct a key (in front of the class) to discriminate between the various members of the class. In theory, you could make the key so complete that at the end of each branch you would have one student's name. In practice, this detail is not necessary. It is helpful to key at least one student all the way to the end. The steps might be as follows:

- 1a Students male (list all male names) go to 2
- 1b Students not male (list other students' names).....
- 2a Over six feet tall (list all names) go to.....3
- 2b Six feet or less in height
- 3a Blue eyes Bill Bailey
- 3b Non-blue eyes

Elicit the discriminants from your class to further increase the interest and participation. In the above example, you would want to emphasize the fact that the only blue eyed male over six feet tall in the class is Bill Bailey. In order that your students may understand how keys are constructed, it is recommended that you have available professionally made keys for your students to observe. A display of keys will also show your students the wide variety, large number and importance of keys

in the life sciences. In activity three, the students construct a key to discriminate between various hardware items. Hardware was chosen to show the arbitrary nature of keys and to show that their use is not limited to living things.

Duplicate the activity pages for "Keys of the Kingdom". One set is recommended per student. Students may do these activities individually or in pairs or small groups. There is much merit in exchanging the keys prepared in "Activity Three" between groups and in having the groups use the key they receive to sort out the hardware items for which the key was constructed to identify. You may wish to introduce the activities briefly on the day prior to their use and assign the reading of the introduction and activity sections as homework.

Activity One:

If possible place on a front desk an example of each of the items mentioned. Identify the objects on the desk and/or shown in the picture in the text. It is quite possible that some of your students may not be familiar with a paper spindle. Have your students quickly read through the key so that they have a general idea of its use. There should be little difficulty with the first key. After the students are sure they understand how it works, assign different groups the responsibility of identifying one of the objects by following the key. For example, one group might begin with the pencil and follow it from number 1 until it is identified. Provide scratch paper and have your students write down the numbers of the steps they follow from number 1 through identification. Upon completion the students should be asked to: identify the basis the writer used in preparing the key to separate the objects in the key. In this particular case, the objects were separated on the basis of physical characteristics. You should be able to elicit this response from your students.

Ask the students to suggest how the key could be varied while still using physical characteristics so that a different sequence could be followed. For example, they might suggest the following:

- 1a. Object has a sharp point at one end.
- 1b. Object does not have a sharp point at one end.

It is important that the student realize that in an artificial key there is no one right way to begin.

Activity Two:

Following the same procedure as before, ask the students to look through the key and designate different groups to trace the various items. Again, have them write down the numbers of the steps they follow.

This key deliberately has several weaknesses built into it which should come out in discussion. When the students, many of whom will be frustrated, have completed the activity, again ask them to identify the basis the writer used in preparing the key to separate the objects in the key.

The answer here would be that the key is based on the function of the object as opposed to the physical characteristics. At this point, ask the students to discuss what problems they had with the key. The built-in weaknesses should become evident very soon. The following problems should be identified and discussed.

1. The terms "large" and "small: are relative and, hence, vague.
2. The process of holding papers in sections 4, 5, and 6 is confusing.
3. In the initial separation of the groups in #1, the term "implement used for writing" is used. Whether or not one wishes to consider an eraser as a writing tool is questionable. One could certainly look at it two ways.
4. The numbering sequence in this key is different from that in the first key and is basically more difficult. It might be pointed out to students that various letter combinations could be used or a mixture of numbers and letters.
5. Students should also note that the vocabulary used in any key has to be appropriate for the people who will be using it.
6. From the discussion, it should also become evident that a key for many organisms should be brief but clarity is most important and should not be sacrificed.

Activity Three:

At this point, students will have identified many of the problems with the key and will offer many suggestions. Direct the students to use this information to prepare a dichotomous key utilizing the hardware items on their desks. Generally, four students working together form a good group. It is helpful to make a board with each of the items fixed and labeled so that students can call the items by their appropriate title.

After the keys are prepared by the students they should be exchanged with other groups. The new students should attempt to use the key.

Have the "user" groups prepare a written evaluation of the key they received. The evaluation should include: the number of items they were correctly able to identify using the key; weaknesses in the key; and improvements which should be made in the key.

In your discussion of the keys point out the various ways in which the keys have been started indicating again that in an artificial key there is not one way which is necessarily correct.

It is often observed that the boys tend to be familiar with the hardware items and, therefore, tend to group things which have similar functions together whereas girls more often rely on the physical characteristics of the items for discrimination.

Notes on the Selection of the Hardware Items for use in Preparing a Key:

To increase the challenge, it is a good idea to include among the hardware items a number of specialty items with which your students have little familiarity. Include such items as: escutcheon pins, roofing nails, rivets, wire nuts, etc.

Among the items should be several that vary only in size, i.e., washers differing in size of opening, wood screws of the same length but varying thicknesses, etc. The object is to force the students to observe closely and identify quantitatively the characteristics necessary to separate the items.

KEY

There is no one "correct" key to separate the items. A workable key is one which uses characteristics which can be observed and agreed upon to distinguish the items.

KEY WORDS

analyze

classifying

dichotomous key

key

organisms

paper spindle

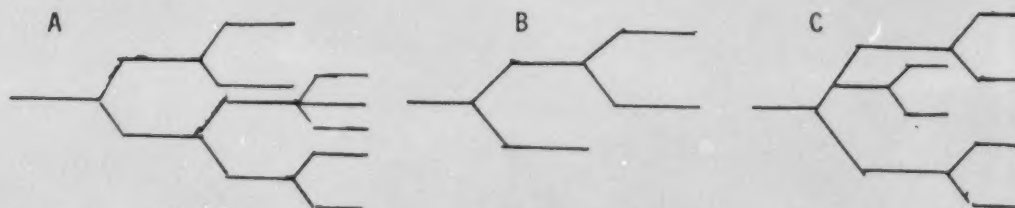
projection

This activity originally appeared in: Guide to Marine Ecology Research.... a curriculum for secondary students. A Marine Ecology Research Project publication.

KEYS TO THE KINGDOM

The seas are full of life. Even Jacques Cousteau can't identify every plant or animal he comes upon in his adventures. How do people deal with this vast assortment of creatures? Because ecology involves studying the relationships among organisms, it is important to be able to identify the organisms present in a study area. To solve the problem of identification, biologists have developed various systems for grouping organisms and methods for identifying them easily and efficiently. Once a preliminary survey of an area has been made, a device called a "Key" is developed for classifying the plants and/or animals in a manner which allows subsequent identification by others studying the area. Just as door keys only open certain locks, identification keys will only work for the organisms and in the area for which they were designed. Keys are very handy. For example, using an appropriate key to identify a fish which you may find, rather than sorting through thousands of pictures of fish or a key to all of the fishes of the Pacific Coast, is a simple and efficient procedure when you understand how a key is organized and you are familiar with its use.

Keys can be designated in different ways, but the most common are called dichotomous (di-kot-e-mus) keys. The term means double branching. Which of the following diagrams would be dichotomous?



In a dichotomous arrangement, you are always offered two choices. The following activities are designed to give you an understanding of how a dichotomous key is organized and a chance to construct one. With this background, you should have few problems using dichotomous keys to common forms of sea life.

ACTIVITY 1

Materials:

Key # 1, Key to Common Objects Found on a Desk

Procedure:

Following your teacher's instructions, analyze "Key # 1, Key to Common Objects Found on a Desk."

ACTIVITY 2

Materials:

Key # 2, Key to Common Objects Found on a Desk

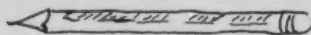
Procedure:

Following your teacher's instructions, analyze "Key # 2, Key to Common Objects Found on a Desk."

OBJECTS



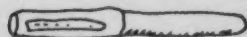
Thumb
Tack



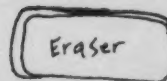
Pencil



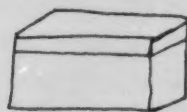
Paper Clip



Fountain Pen



Eraser



Card Box



Paper Spindle

KEY # 1

A KEY TO COMMON OBJECTS FOUND ON A DESK

- 1a Object made entirely of metal 2
- 1b Object not made entirely of metal 5
 - 2a Object has no thin metal projections 4
 - 2b Object is flat at one end with a sharp projection
coming from the center 3
- 3a Flat end is no larger than 1 cm thumb tack
- 3b Flat end (base) is at least 5 cm in diameter....paper spindle
 - 4a Object is made of bent wire paper clip
 - 4b Object is "box shape" with a hinged lid.....card box
- 5a Object made entirely of rubber eraser
- 5b Object may have rubber in part 6
 - 6a Object is long, thin, has graphite inside and has
rubber at one end pencil
 - 6b Object is long, thin, has removeable cap, but
does not have rubber at either end fountain pen

KEY # 2

A KEY TO COMMON OBJECTS FOUND ON A DESK

- 1. Object is used in the process of writing 2
 - Object is not used in the process of writing..... 4
- 2. Object has a cap and contains a fluid which is imparted to
paper with the process of writing.....fountain pen
 - Object does not contain fluid..... 3
- 3. Object is long and slender, containing a dark,
solid material used to mark paper in the process of
writing pencil
 - Object is made of rubber and used to "eradicate"
or remove lines in the process of writing.....eraser
- 4. Object is used to keep papers together..... 5
 - Object is used to attach papers to a wall or
solid object..... thumb tack
- 5. Object is small and metal and used to keep small
numbers of paper sheets together paper clip
 - Object is used to keep larger number of sheets together.....6

6. Object holds papers together by securing them on a metal shaft with a sharp point spindle
Object is designed to arrange papers of uniform size so they do not spill and become mixed up.....card box

ACTIVITY 3

Materials:

An assortment of 10 or more different hardware items such as nuts, bolts, machine screws, wood screws (flat head, round head and Phillips head), nails (including specialty nails), washers, wing nuts, cotter pins, lock washers, etc.

Procedure:

Your teacher will give you a series of objects which you may consider to represent a collection of common life forms found in a lake, river or bay. Based on the knowledge gained in Activities # 1 and # 2, prepare a "Key to Common Hardware Objects" which would be appropriate for any student in your class. Your success is directly related to the ease with which others in the class can use your key.



TEACHER BACKGROUND - Key to Identification of Some Common Marine Algae of the Puget Sound

The following key may be used as an aid to the identification of the most common marine algae found in the Puget Sound. As with all keys, this key is designed to separate the Puget Sound genera listed in the key. This key was developed at the Marine Science Center to help students identify local algae. The key uses familiar terminology and is relatively easy to use. It is recommended that you have your students analyze and criticize the key after they have used it to separate algae. The key contains some choices which are not altogether clear (e.g., "Plant with branching parts plantlike."). Nonetheless, the key is useful, especially when coupled with a text which includes pictures of the algae. The text may be used for verification of the keyed results.

Duplicate the key pages. One set per student is recommended. Provide trays of algae or mounted specimens (without labels) for identification. Students may work in small groups or individually. Circulate between student groups as they key out their specimens. Offer advice and help but let your students make the decisions regarding choice of which branch to follow. Plan to allow time for a discussion of the key and its shortcomings and to identify the species of algae.

Since it is not always possible or convenient to obtain fresh algae specimens, you may want to consider making a class set of pressed algae herbarium specimens following the suggestions given in "Pressing Algae". Be sure to include a sufficient portion of the plant to allow identification.

KEY WORDS

In addition to genus names:

blade

holdfast

stem

tufts

vein

KEY TO IDENTIFICATION OF SOME COMMON MARINE ALGAE OF THE PUGET SOUND

1. Plant green. (2)
1. Color of plant brown or red. (5)
 2. Plant grass-like (with roots). ZOSTERA (just out of tidal zone)
 2. Plant not grass-like (3)
3. Plant grows in tufts and looks like green sea hair in the water. Usually in rock pools. SEA HAIR (CLADOPHORA).
3. Plant not hair like. (4)
 4. Plant blade-like with round hollow stem. Blade of plant about $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches wide. Found growing on rocks or other plants.

ENTEROMORPHA

4. Plant blade-like with many holes. Looks like wilted lettuce that has been torn. Stem is flat. SEA LETTUCE (ULVA)
5. Plants olive green, tan or dark brown in color. (6)
5. Plants redish, rose red, purple brown, brownish red or almost black (16).
6. Plant with no branches. Looks like a green rumpled up sponge.

LEATHESIA.

6. Plant with branching parts plantlike. (7)
7. Plant found growing on Zostera (eel grass). About the size of a bottle cap.

PUNCTARIA

7. Plants other. (8)
8. Plant olive brown. Grows in single stems. Looks like sausage links that taper to a point at the top.

SCYTOSIPHON

8. Plant not in single stems. (9)
9. Plant dark brown to black. Round stem that attaches to bottom. A single wide blade, very thin and flat, long pointed ping pong paddle. (10)
9. Plant not flat or blade like. (11)

10. Plant blade has 5 lines from top to bottom. COSTARIA
10. Plant blade usually splits into 3 to 8 long strips. LAMINARIA
11. Plant with great long stem up to 25 yards long. The top is shaped like a light bulb with 6 to 8 flat blades growing from it, without hair. Looks like a bull whip--bullkelp. NEREOCYSTIS
11. Plant with a type of branching. (12)
 12. Plant with stem, next to the holdfast 10 to 40 leaves grow straight out. The rest of the stem is a wide leaf with ruffled edges. Its length is up to 40 feet. ALARIA
 12. Plant with more branches. (13)
13. Flat leaves grow from flat branches. The end of each leaf has two bulbs with bumps on them. FUCUS
13. Leaves grow from flat or round branches. (14)
 14. Plants with many small round to oval bulbs on each branch. (15)
 14. Plant with round or flat branches with no bulbs. Excretes sulfur and will kill other plants around it as well as itself. Many different forms; one species blade like. DESMARESTIA
15. Plant branches with bulbs that have a leaf growing from the head of each bulb.

MACROCYSTIS

 15. Plant branches with bulbs without leaves growing from them. SARGASSUM
 16. Plant branches with many hard shell-like segments growing on top of each other. Usually redish pink in color. CORALLINA
 16. Plant not hard or shell-like. (17)
 17. Plant large and flat. (18)
 17. Plant not large and flat. (23)
 18. Plant with very little stem or no stem at all. Brownish purple in color. There is no branching. PORPHYRA
 18. Plant with branching. (19)
 19. Plant on stem and blade grows on the blades of eel grass. Purplish red to deep purple in color. SMITHORS
 19. Plant flat with branching from stem. (20)
 20. Plant with branching from stem. Large forms only. (21)

20. Plant with branching from stem and there are small types to large types. (22)
21. Plant in water or out. Shines a blue or purplish blue color. IRIDEA
21. Plant when put up to light shows many vein-like lines throughout the whole plant. POLYNEURA
22. Plant with very rough surface like very heavy sandpaper or a rough towel. GIGARTINA
22. Plant large, some small sizes. Blade-like leaves have small holes over the entire surface. RODYMENTIA Small sizes do not have holes.
23. Plant has round stems and round branches. No flat leaves. Up to 18 inches long. AGARDHIELLA
23. Plant has flat stem and branches. (24)
24. Plant stem is long broad and flat, tapering like a ribbon, with small flat branching leaves sticking out here and there. PRIONITIS
24. Plant stem and blades flat. Holdfast somewhat rounded. Some blades look like flattened hands. End of branches are split. CALLOPHYLLIS

TEACHER BACKGROUND - Pressing Algae

Algae pressing can help to make seaweeds interesting to your students. The techniques are simple but somewhat time consuming. In collecting algae in the field, place all specimens from a particular habitat in a plastic bag. Include a label with pertinent information including date, location, collector, and habitat along with identification if known at this point. It is suggested that you choose the best specimens each year and use these to build up a school phycology (algae) collection. Herbarium paper is the standard used, but typing paper or 3 x 5 cards will work if you select only parts of the algae. The procedures do not differ greatly from those used in pressing land plants. However, algae need more pressure applied than standard botanical mounts. If the newspaper and wax paper are not changed on a regular basis the algae will begin to adhere to the wax paper. Have the students exercise care in choosing the portion of algae for mounting. The best portions should be utilized. The same procedures may be used for freshwater algae.

Duplicate "Pressing Algae". One set per student is recommended. Students may work together or in small groups. Before having the students begin, display a plant press and its component parts. Ready one plant for pressing and place it in the press with the proper blotters etc.

Provide ample resource books so that students may identify and learn more about their plants.

Display the pressed and labeled algae on a classroom bulletin board.

KEY WORDS

algae
blotter paper
corrugated cardboard
fronds
holdfasts
intertidal zone
mounting
plywood
pressing
regulated
specimen

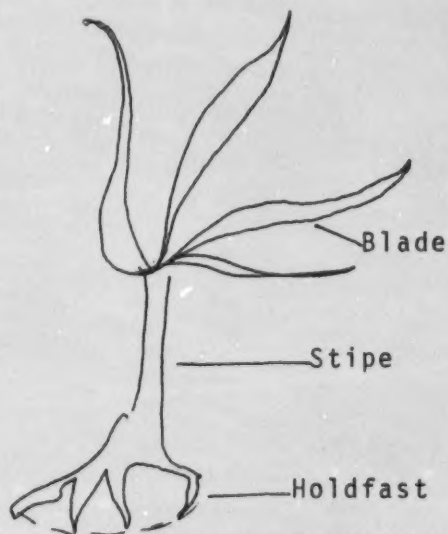
Pressing Algae

Many kinds of algae can be found along the seashore. Pressing and mounting algae will help you learn more about them. The algae you collect at the beach can be pressed and mounted in the classroom if you keep it in a plastic bag while you transport it. Use reference books to help you identify the algae you collect.

Collecting organisms, including plants, from the intertidal zone is regulated by state and federal agencies. Check the local regulations carefully before going to the seashore.

Materials:

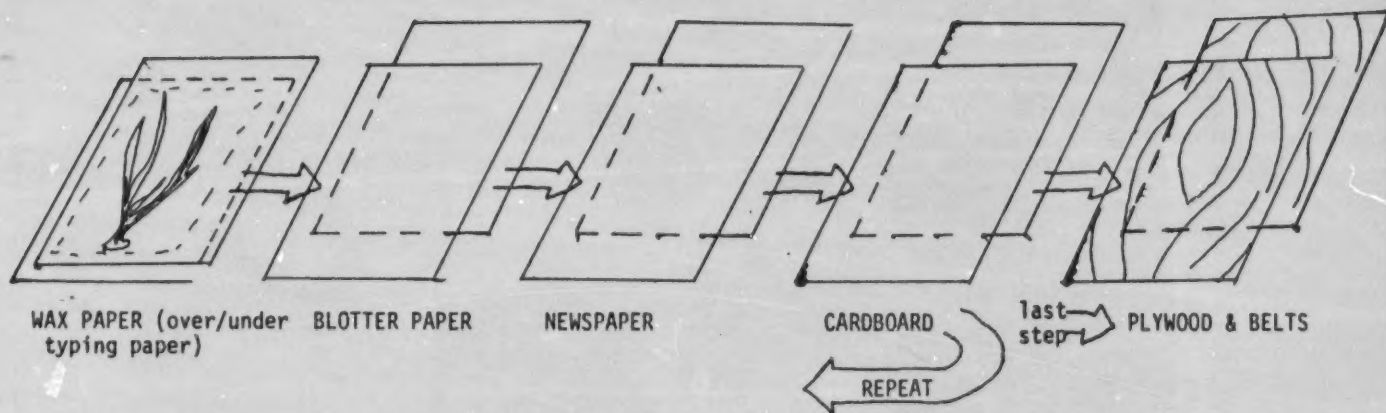
shallow pan (cafeteria trays work well)
waxed paper
typing paper
blotter paper
newspaper
mounting paper
corrugated cardboard
two pieces of plywood
two belts or a length of rope



Procedure:

1. Collect algae specimens. Algae specimens which are attached should be collected with the holdfasts intact. The algae should be kept wet until it is to be mounted. If it is necessary to put off sorting until the next day, aeration is required to maintain the minute animal forms living on the algae. If they die, the algae in the holding tank will spoil.

SETTING UP THE PLANT PRESS



2. Float the algae in the shallow pan so you can arrange the fronds (leaves). Then slip a sheet of typing paper under the algae and carefully lift it out of the water. If this proves too messy, place the algae on the typing paper and arrange the fronds the best you can.
3. Put a piece of waxed paper on each side of the specimen so it does not stick to the other papers that are placed on it.
4. Next, place a layer of blotter paper (put your initials on it) and then a layer of newspaper on each side of the specimen to absorb excess moisture from the plant.
5. Put a sheet of cardboard on each side of the papers. Use hollow-type cardboard to allow air to circulate.
6. Repeat these steps for each specimen you want to press.
7. After you have prepared all your specimens for pressing, place one piece of plywood on each side of the stack and secure it tightly with the belts or rope.
8. Set the plant press near a heater or in any other warm place where there is circulating air.
9. Change the layers of blotter paper and newspaper once a day so drying is thorough. Dry blotters for re-use. Two to five days will be required to press the algae.

10. When the plants are completely dry, glue each plant to a piece of mounting paper and label. Be sure to list the name of the plant; the place of collection; the date; a description of the habitat in which the specimen was collected; name of the collector, and any special remarks about the specimen.

TEACHER BACKGROUND - Farming Four Feet Under - Three Level Guide

As the human population increases, demands upon the resources of the sea also increase. "Farming - Four Feet Under" describes research aimed at increasing man's use of the sea through the culture and harvest of seaweed. The article is a largely non-technical summary of research, conducted in the Puget Sound, which presents some of the concerns of and methods used by research scientists. Be aware that this article tends to minimize the unknown and possible deleterious side affects of algae culture. The increasing use of algae derivatives will make seaweed culture more attractive. "Farming - Four Feet Under" gives your students a glimpse into this future activity.

This article is difficult reading for many students. This article seems to typify a problem seen in teaching today; we can have articles that cover the material but are too difficult to read or we can have articles that can be read but do not cover the material. The three level guide presented here is one way to solve this seeming dilemma. Three level guides are based on what seems to be the general agreement that comprehension can take place at different levels of cognition. Harold L. Herber has called these levels 1) literal; 2) interpretive; and 3) applied. With the exception of the literal level, each level requires the product of the previous level or levels in order to function. The literal level of comprehension produces knowledge of what the author said. We all recognize that it is quite possible to identify and even repeat what an author has said without understanding what the author meant by his statements. The interpretive level of comprehension depends upon the reading performed at the literal level but carries the process a step further. At this level the reader derives meaning from what the author has said. The meaning is determined by the way the reader perceives the intratext relationships. The applied level of comprehension takes the product of the literal, (what the author has said) and the interpretive (what the author meant by what he said) and applies it in some practical or theoretical exercise. At this level the reader is using his past experiences and knowledge to produce new ideas which extend beyond those

immediately identifiable in the reading selection. It must be borne in mind that the level at which a person reads does not reflect upon her intelligence and that the level can change as the material changes. The most advanced engineers and scientists often read at the literal level if they cross into other disciplines. When we read materials from an area with which we have little familiarity, our level of comprehension goes down. Your students are no exception to this observation. The three level guide is a device used to improve a person's comprehension by focusing on important concepts at each of the three levels. The three level guide can be used with any material and is readily constructed. For aid in this regard please see:

Teaching Reading in the Content Areas. 1970. Harold L. Herber.

Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 296 pages.

Duplicate the pages of the three level guide; one set per student.

Spend a few minutes describing what is expected of the student. Suggest that the students read the statements in the three level guide before they read the article. In this way, the statements serve as a preview and your students will be looking for and expecting to see certain concepts. You may elect to have your students compare their answers by meeting in small groups. The process of resolving differences in opinion can be very instructive. Upon completion of the reading of the three level guide, discuss the guide by reference to the article. It is sometimes helpful to have your students note the page number and paragraph number where they found evidence supporting or refuting the statements in the guide. You can require your students to provide this information or you can offer extra credit for those that include it. Choose the technique that most appeals to you and best fits the needs and skills of your class.

KEY WORDS

Carrageenin

culture

extracts

relationships

seaweed

KEY

"FARMING - FOUR FEET UNDER" - Three Level Guide

Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those that you believe say what the author actually said or paraphrased in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference. Also, be ready to explain what is inaccurate about the statements that you do not check.

- ☒ Research is being conducted aimed at growing seaweed as a crop for the production of carrageenin.
- ☒ Harvesting wild stocks of seaweeds is often dangerous and unproductive.
- ☐ The Department of Natural Resources (DNR) cannot encourage the establishment of marine industries.
- ☒ To culture seaweeds, nylon nets (stretched over plastic pipes) are placed in wild seaweed beds.
- ☐ The seaweed harvester used currently separates the seaweed blades from the nets and draws the blades to the surface to a waiting barge.
- ☒ Net cultured plant yield is less than tank cultured but is catching up.
- ☒ U.S. demand for seaweed extracts is currently being met by foreign countries.

Directions: Now compare your answers with those of others in your group. If there are many differences, find the page and paragraph that support your answer and write them next to the statement in question. When you finish your discussion, go on to the next level.

Level II. Directions: The statements below may or may not be true. Check each statement you believe is a generalization the author himself draws based on the information he gives in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference.

- ☒ Seaweed culture could become an important new industry in the Puget Sound.
- ☒ Different researchers have different theories regarding how to make seaweed culture a reality.

_____ Seaweed culture may be possible in areas in which we do not now find seaweed growth.

☒ _____ The next thrust of research will involve economic and technical considerations.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to next level.

Level III. Directions: Read each statement below, relating the details and author's interpretations drawn from the selection to ideas and experiences you've had in reference to this topic. In column A, check the statements with which Mumford would have agreed. In column B, check the statements with which you agree.

A	B
_____	_____ We currently know enough about the relationships that exist between plants and animals in the sea to accurately predict the changes that will occur due to widespread algae culture.
☒ _____	_____ Algae culture is an important means for reducing our dependence upon other nations for an adequate supply of the algae derivatives used in many industries.
☒ _____	_____ More research is needed before net culture should be implemented on a large scale.
☒ _____	_____ In the future, man will need to more fully utilize the resources of the seas.
☒ _____	_____ There's big money in algae!

Directions: Again, compare your answers with your group. Where there are differences, try to resolve them.

Farming —

Four Feet Under

It sounds like a farmer's dream — a crop that "seeds" itself, needs no fertilizer or supplemental nutrients, does not require artificial irrigation, will produce up to three sizeable harvests per year, and sells for around \$500 a metric ton (dryweight).

There are, however, a few problems with the dream. The "crop", even at the lowest tide levels is under about four feet of water and needs swift currents to achieve maximum growth. And, at the current state-of-the-art, it must be harvested by hand.

The crop is seaweed, or more specifically, the species *Iridaea cordata* and *Gigartina exasperata*, which produce a commercially valuable extract called carrageenin. The extract is widely used as a suspension agent in enterprises as diverse as food processing and paintmaking.

And the problems associated with seaweed farming, though looming large at the moment, may be on their way to solution through research sponsored by the Washington Department of Natural Resources (DNR) and the Washington Sea Grant Program.

Dr. Tom Mumford, DNR marine biologist, and Dr. J. Robert Waaland of the Department of Botany at the University of Washington are two researchers who hope to provide the technical base to turn seaweed farming into a commercially viable enterprise. They're looking at all aspects of seaweed culture, from finding the hardiest, highest-yield strains to development of a mechanical harvester.

Dr. David Jamison, formerly employed by DNR and now with the

State Department of Ecology, was the first to see the commercial potential of Washington's seaweed resource, Dr. Mumford said. "He worked with groups in 1970 to explore harvesting the existing wild stocks. But there were numerous problems." Among these were the dangerous locations of the wild populations—primarily areas of strong currents, accessible only by boat — and the small amounts the harvest yielded in proportion to the harvesting time expended.

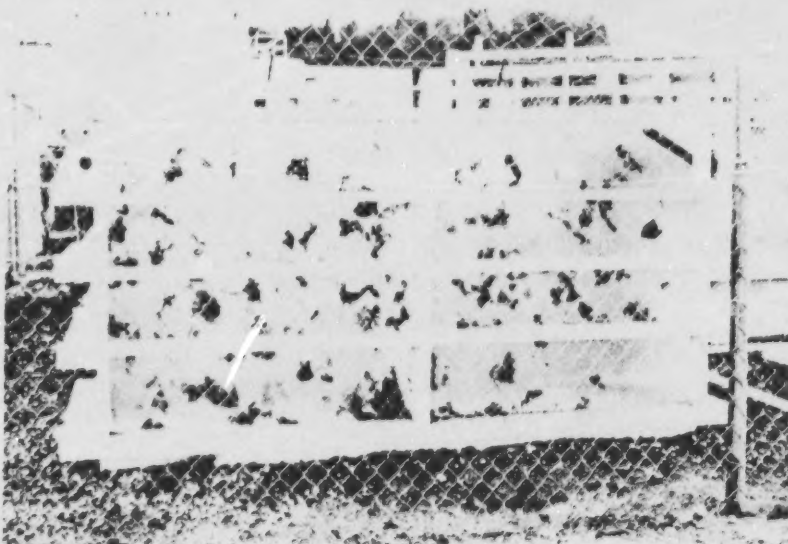
Little was known about the ability of wild populations to re-seed nor was there much knowledge about optimum growing conditions.

But the prospect of enhancing the balanced use of marine lands, one of the operating functions of DNR, and of encouraging the establishment of a new, clean marine resource industry still existed. "The basic research work was

continued by my predecessor at DNR, Cliff Kemp," Dr. Mumford said. "In fact, it was Cliff who discovered you can put a net on a bed of seaweed and spores from the seaweed will set on the net and grow. Cliff did this on a small scale."

To propagate the natural seaweed stocks, nylon nets stretched over plastic pipe frames were placed in wild seaweed beds in early fall. Spores from the mature seaweed settled onto the nets and began to grow. In the spring, the nets were moved to locations where the water, even at low tide, was deep enough to afford the young seaweed blades protection from the sun, and where strong currents existed.

In the summertime, nets are selectively harvested, taking only blades of about one meter (approximately 39 1/2 inches). Smaller blades



Constantly circulating water is essential to the well-being of seaweed plants grown in this experimental tank.

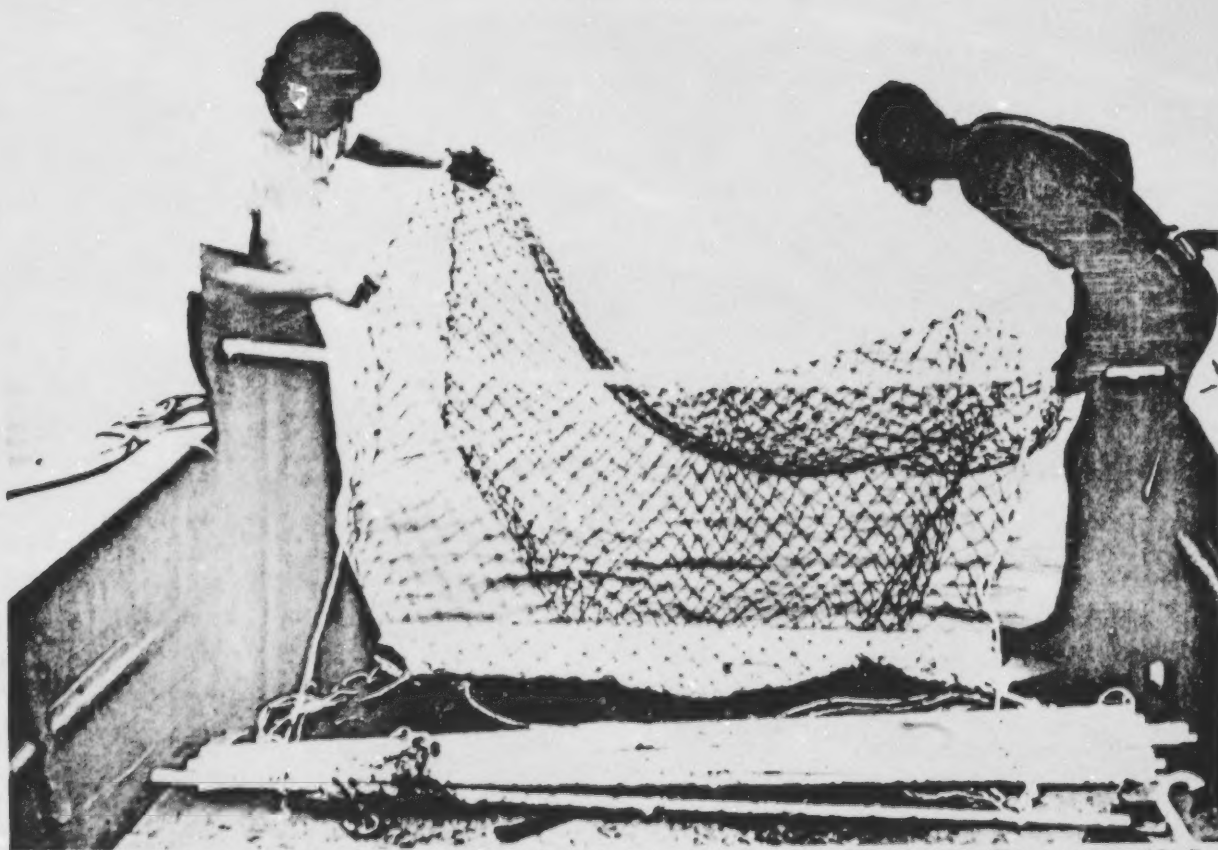


This *Iridaea cordata* plant, measuring about .5 meters (approximately 20 inches) long was transplanted from laboratory conditions to natural waters as part of seaweed growth rate studies.

are left on the net to grow. A "hold fast" or small button at the base of the plant fixes it to the net. Generally, a dozen blades will emerge from a single hold fast. Usually only one blade grows to its full length, but smaller blades still are commercially valuable.

From a tiny beginning, the natural seeding experiments have progressed to a full scale test bed located just off Barnes Island, a bit of land north of Orcas Island in the San Juan chain. Twenty-five quarter-meter-square nets are in place, wired to cement blocks to anchor them in the currents.

"The system we're dealing with at Barnes Island is fairly natural. We're dependent on Mother Nature



Nets for natural seeding of seaweed are inspected carefully before being lowered into the waters off Barnes Island. (Photos courtesy of Dr. Tom Mumford and Dr. J. Robert Waaland.)

to see to it that seaweed spores come to rest and grow on our nets. We're not manipulating the environment by adding nutrients or fertilizer to the water," Dr. Mumford said.

While the natural system hopefully flourishes, Dr. Mumford and his colleagues will be carefully measuring a number of factors. Growth rates will be checked against such variables as sunlight and water movement. Net sizes ranging from three to six-inch mesh will be monitored to determine which will hold and bring to maturity the largest number of plants. Similar measurements and evaluations are being made at smaller test beds in the southern part of Puget Sound and on the Ocean Coast.

Concurrent with the experiments in natural seeding, Dr. Waaland has investigated methods of growing seaweed in laboratory conditions. It was during early attempts at tank culture of seaweed that the importance of moving water to the survival of the plants became apparent.

"In the preliminary experiments in the spring of 1973, we used cylindrical tanks with no provision for agitating the water or the plants," Dr. Waaland said. "There was little or no growth. Within a few weeks the plants had deteriorated."

Since that time, experiments have been conducted using tanks with constant aeration. "We believe the water motion near the plant surface replenishes nutrients in the boundary layer immediately adjacent to the plant surface," Dr. Waaland said. "The addition of aeration almost immediately increased the yield — by about six times — over the net cultured plants, although the rate of yield from net cultures now is catching up to the tank cultured plants."

The use of tanks for growing seaweed offers the possibility for selection of strains with commercially-desirable characteristics, such as rapid growth, Dr. Waaland said. In some cases it may also be possible to increase the plants' carrageenin content by manipulation of the nutrient

content of the water. Laboratory or control situations also are used to measure the optimum light, either natural or artificial, necessary for strong plant growth and to test measures for discouraging growth of other naturally present but less desirable species that can rob seaweed of nutrients.

Dr. Mumford and Dr. Waaland agree that solutions to the biological problems involved in seaweed farming are within reach. But there are still technical and socio-economic barriers to be hurdled before seaweed farming can progress from

research to commercial venture. Chief among these is the problem of harvesting. "What we're looking for is a sort of sea-going combine," Dr. Mumford explained. The best machine, he noted, would be able to separate the seaweed blades from the nets and then draw them to the surface to a waiting barge.

Both researchers feel that seaweed farming would be a beneficial use of the state's tidelands resource. "We would be encouraging private industry to come in and use state-owned bedlands for this purpose in exactly



Dr. Tom Mumford, Department of Natural Resources marine biologist, examines seaweed growth on a naturally seeded test bed net.



Carrageenin extracted from this seaweed has a variety of commercial uses, including food processing, paint manufacture and the making of toothpaste.

the same way sharecroppers use the state's agricultural lands. That's definitely within the charge of responsibility to the Department (of Natural Resources)," Dr. Mumford said. According to Dr. Waaland, the bulk of the tidelands suitable for seaweed farming are not utilized for other marine resource activities, such as clam beds. And because generally shallow waters would be utilized, there would be little or no interference with recreational use of the water, such as boating or fishing, Dr. Mumford noted.

A U.S. market for the seaweed's carrageenin extract already exists and currently is being met by imports from countries such as the Philippines and Chile, where wild stocks are harvested using inexpensive local labor. With the establishment of a stable domestic market for the carrageenin-producing species, new uses and markets could be opened up.

"Food production from seaweeds is only one possibility. The Japanese already consider it an everyday food," Dr. Mumford said. He noted that there are at least 30 edible types of seaweed that can be grown in Washington waters.

Seaweed is considered an excellent source of iodine and vitamins. In addition to carbohydrates, fats, and proteins, seaweed contains vitamins A, B-complex, and C, sodium, iodine, and trace elements. ☼

"FARMING - FOUR FEET UNDER" - Three Level Guide

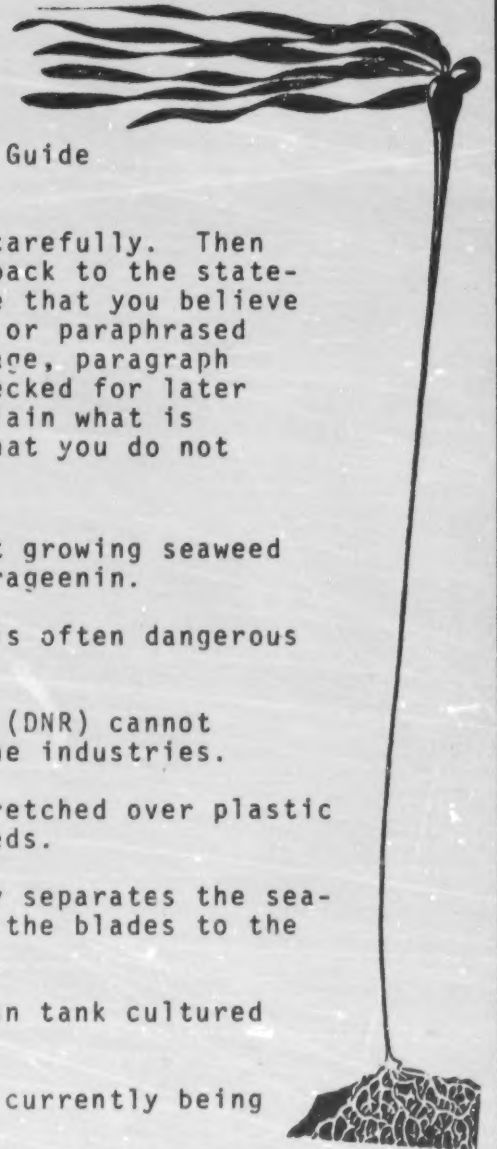
Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those that you believe say what the author actually said or paraphrased in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference. Also, be ready to explain what is inaccurate about the statements that you do not check.

- _____ Research is being conducted aimed at growing seaweed as a crop for the production of carrageenin.
- _____ Harvesting wild stocks of seaweeds is often dangerous and unproductive.
- _____ The Department of Natural Resources (DNR) cannot encourage the establishment of marine industries.
- _____ To culture seaweeds, nylon nets (stretched over plastic pipes) are placed in wild seaweed beds.
- _____ The seaweed harvester used currently separates the seaweed blades from the nets and draws the blades to the surface to a waiting barge.
- _____ Net cultured plant yield is less than tank cultured but is catching up.
- _____ U.S. demand for seaweed extracts is currently being met by foreign countries.

Directions: Now compare your answers with those of others in your group. If there are many differences, find the page and paragraph that support your answer and write them next to the statement in question. When you finish your discussion, go on to the next level.

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- _____ Seaweed culture could become an important new industry in the Puget Sound.
- _____ Different researchers have different theories regarding how to make seaweed culture a reality.



_____ Seaweed culture may be possible in areas in which we do not now find seaweed growth.

_____ The next thrust of research will involve economic and technical considerations.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to next level.

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A	B	
_____	_____	We currently know enough about the relationships that exist between plants and animals in the sea to accurately predict the changes that will occur due to widespread algae culture.
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_____	_____	More research is needed before net culture should be implemented on a large scale.
_____	_____	In the future, man will need to more fully utilize the resources of the seas.
_____	_____	There's big money in algae!

Directions: Again, compare your answers with your group. Where there are differences, try to resolve them.

TEACHER BACKGROUND - One Step Further

"One Step Further" provides your students with an opportunity to further their graph reading skills by utilizing two graphs from a technical paper¹ prepared by Tom Mumford, the biologist mentioned in "Farming - Four Feet Under" the article read by your students

Duplicate the activity pages; one set per student. Plan to allow time for a discussion of the graphs and to answer the questions.

KEY

Figure 1

1. Net 2A was harvested about June 10 and October 15 (the dates must be extrapolated from the graph so some variation is permitted).
Net 2B was harvested about July 20 and again on October 15.
2. The net had a three inch mesh.
3. The highest wet weight found on Net 2B occurred about July 10. (The weight was about 5.5 kg/0.25m²).
4. The rapid decreases seen June 10 and July 20 are a result of harvesting.
5. According to Figure 1, the period of most rapid growth for Iridaea cordata occurs from April to the first part of July.
6. For Net 2B the optimal harvest time in 1976 was about June 10. After this date the wet weight per 0.25m² began to decrease.

Figure 2

1. June and July had the highest average growth rate (from June 15 to July 15)
2. During the first half of October, the average growth rate was about minus 15 grams of salt-free dry matter per day per meter square.
The plants actually lost weight.
3. The growth rate from August 15 to November 15 was negative. This kind of growth rate might be explained by overharvesting - more material was being removed than was being produced. The harvesting might have been by marine herbivores or by man, we can't really tell from the data. Storms or disease could also cause the results observed.

4. According to figure 2, the optimal time for harvest would have been about July 12. This figure should agree closely with the answer for number 6 on the preceeding page.

¹Romeo, Judie, editor. 1977. "Farming-Four Feet Under." Pacific Northwest Sea. Vol. 9, No. 3:11 - 14.

One Step Further

The two graphs which follow were prepared by Tom Mumford and describe some of the results of his studies. Use the two graphs to answer the following questions.

Figure 1

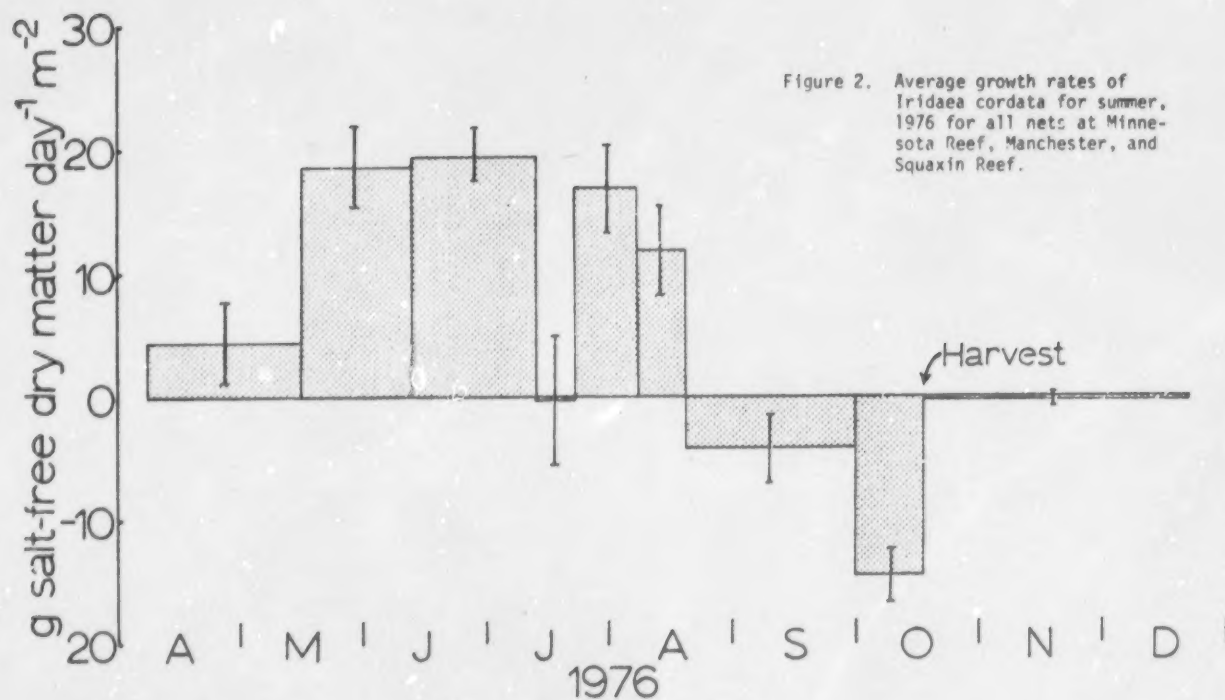
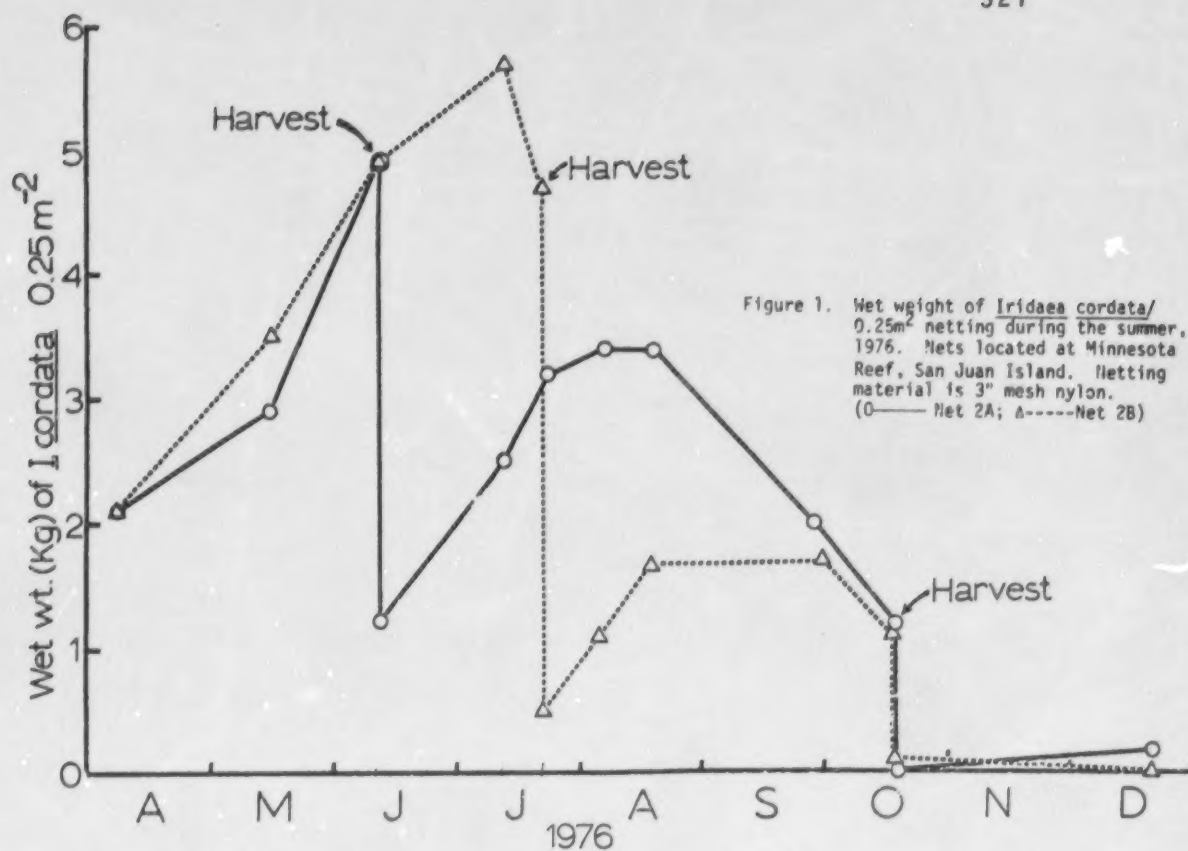
1. When was net 2A harvested? Net 2B?
2. How large was the net mesh?
3. When was the highest wet weight found on Net 2B?
4. What accounts for the rapid decreases seen at June 10 and July 20?
5. According to figure 1, when does the period of most active growth occur for Iridaea cordata?
6. For Net 2B when did the optimal (best) time for harvest occur in 1976?

Figure 2

1. Which month (s) had the highest average growth rate?
2. What was the average growth rate during the first half of October?
3. How can you explain growth rates like those seen from August 15 to November 15?

4. When did the optimal time for harvest occur in 1976 according to figure 2?

How does this date agree with your answer for number 6 on the preceding page?



BIOLOGICAL FACTORS:

Animals - The Consumers

TEACHER BACKGROUND - Animals!

"Animals!" is an introduction to the taxonomy of marine animals. The diversity of marine life makes it impossible for any one person to identify all forms unaided. Scientific classification schemes allow the observer to sort organisms into groups of related creatures. During this activity it is important to keep in mind that classification systems are human constructs which help us make sense out of our observations. The system was made to fit the organisms and not vice versa.

A reasonable sampler of the half million or so known marine animals can be conducted via films. In fact, the diversity of marine life and many of the ecological principles studied in this unit are best illustrated by film. Consult your local film catalog for the films available to you and choose accordingly.

There are many possible sources of the marine organisms needed. The best source would be a class field trip to a local shore.

Preserved specimens from previous years may be used. Many varieties of marine life, both live and preserved, are available for purchase from biological supply houses such as:

Carolina Biological Supply Company
Burlington, North Carolina 27215

or

Powell Laboratories Division
Gladstone, Oregon 97027

Ward's of California
316 Cannery Row Box 1749
Monterey, California 93940

You may have students who dive or whose parents dive. These people are often happy to provide specimens. Local dive shops can also be a good source. Local museums sometimes have a circulating collection of preserved specimens. A little investigation can usually yield a suitable assortment of animals at little or no cost.

If you elect to collect your own specimens, be sure to check tides (low tides are best for collecting) and local and state regulations governing collecting marine organisms. Also, please read the general comments on collecting found in the introduction to this guide. Collect only what is needed. Live specimens are always better than preserved ones. If you plan to take live specimens, be sure there is adequate space in your salt water aquarium. If you do not have a marine aquarium, you may wish to

start one now. General instructions may be found in "Marine Aquaria in the Classroom". If you do not have facilities or room, you may preserve the specimens in 70% ethyl alcohol in sea water. Special techniques are required for preservation in formalin since formalin tends to cause the soft parts of animals to disintegrate and can even damage the hard parts of many animals.

At low tide, specimens can simply be picked up from the beach. Wading in shallow water can also yield an assortment of animals. Nets made of hardware cloth, plastic screening, or nylon mesh can be used. Diving masks or glass bottom buckets are a great help in locating specimens. The use of scuba gear by students on field trips is not recommended due to the risk involved. Every student should have a field notebook to record all details of the field trip: the date, exact location of the collecting area, weather and tide information. Every specimen should be marked with a label giving collector, location, date and habitat.

Duplicate the activity pages. One set is recommended per student. The introduction for this investigation may be assigned as homework. The investigation is best conducted in small groups. Use your students' expertise when you begin to sort the animals. Provide copies of "A Summary of Marine Animal Phyla" and any other reference materials you might have. A list of useful books follows. Try and provide a wide variety of common animals. Remember that the purpose of this investigation is to introduce your students to the major marine phyla. Detailed study of certain species will come later. This exercise should serve as an overview of the marine environment. Plan to allow time for a discussion of the classification results and to provide answers to the questions found in the text.

KEY

1. a. The basis for biological classification is similarity of structure.
- b. Lots of other methods could be used to classify plants and animals: size, color, alphabetical listing of names, weight, age, etc. These other criteria are not very useful since they tell us nothing about the relationships between organisms.

2. Taxonomists can tell us much about the relationship of the named organism to other organisms both living and dead. Their classification can tell us what organisms are structurally similar to the organism named and the degree of similarity. Taxonomists fit organisms into a hierarchical scheme that tells us about the organism in question in relation to all other organisms.
3. The two animals in the same genus are more closely related than the two in the same family since the genus level of sorting reflects more similarities than the family level. The genus level is lower in the hierarchy than the family level and, hence, members of the same genus are more similar than members of the same family who are in different genera.
4. Since the other crab is able to mate and produce fertile offspring it must, by definition, belong to the same genus and species as the Dungeness crab. The mystery crab is a Cancer magister. Remind your students that the definition of the species level is the ability to mate and produce fertile offspring.
5. The species name glacialis sounds quite a bit like "glacial" which might give us a hint that the Right Whale lives in the cold waters near the Poles. Use this question to show your students that, while the scientific names sound like very impressive Greek and/or Latin words, they are often simply "latinized" words that describe something significant about the organism in question.

KEY WORDS

anatomy

biological classification

class

classification

external

family

genus

habitat

kingdom

luminescence

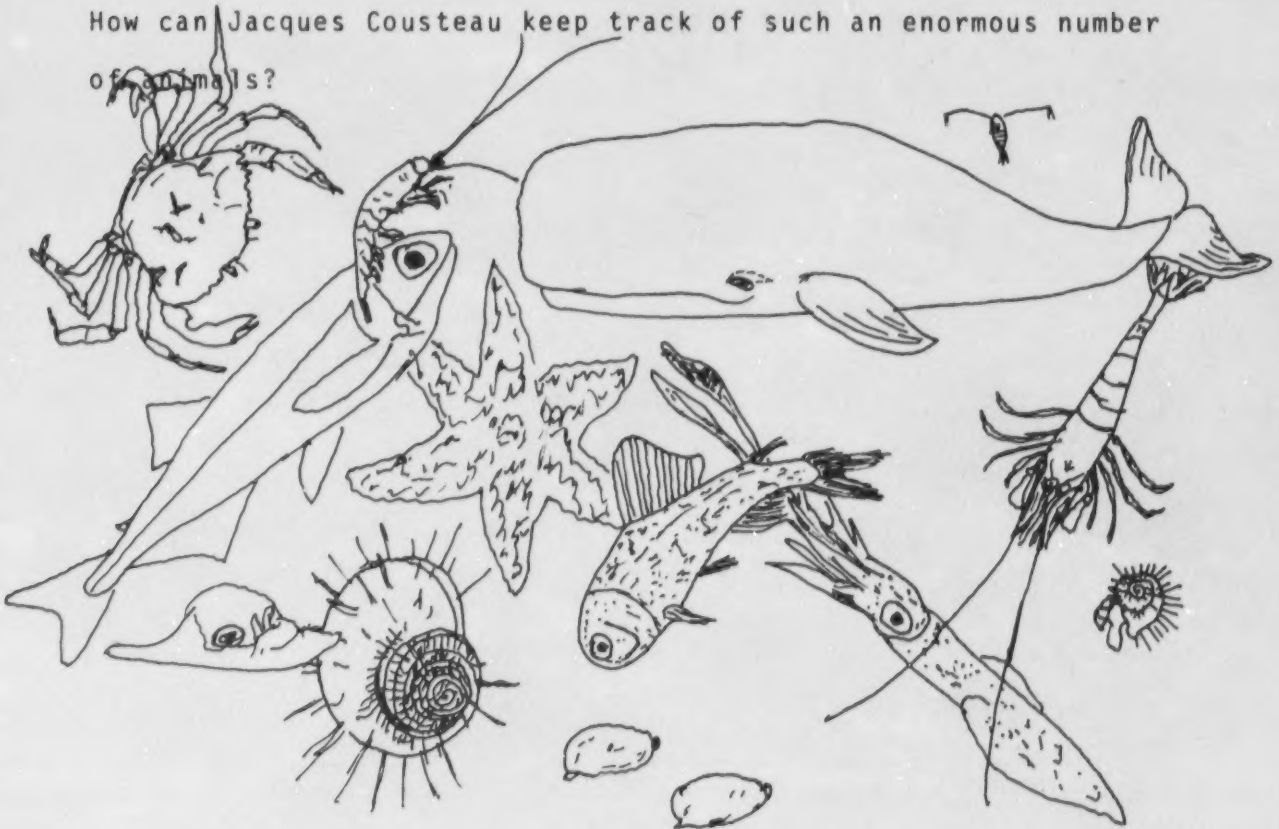
nematocyst
 order
 organism
 phylum
 radial
 relationship
 scientific name
 species
 spicules
 symmetry
 taxonomist
 taxonomy

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ANIMALS!

Over 500,000 different kinds of animals live in the seas. How can Jacques Cousteau keep track of such an enormous number of animals?



Man has always been interested in naming and grouping animals. Before the dawn of civilization, man had to distinguish between animals he could eat and animals that could eat him. As knowledge increased and travel became more common, the number of animals known to man increased. It became more and more necessary to have a system for grouping or classifying animals. How could he classify these thousands of animals? One way would be to classify them alphabetically. This would help but it wouldn't tell us very much about the relationships of the animals. Biological classification is based on similarities in structure.

Generally, the more similar the structure, the more closely the animals are related.

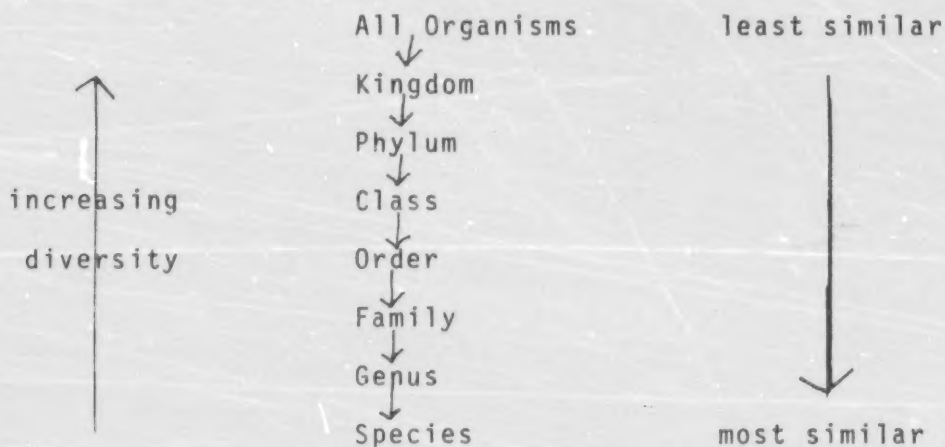
1. a. What is the basis for biological classification?
- b. What other methods could be used for classification?

Taxonomists, scientists who classify plants and animals, have developed a hierarchical (layered) system for sorting organisms. The first sorting results in the establishment of the kingdom level. Some taxonomists place all living things in one of two kingdoms, plant kingdom or animal kingdom. Others place all living things in one of three kingdoms, plant kingdom, animal kingdom or protist kingdom (microscopic bacteria, etc.). Which system is "right"? The differences of opinion point up the fact that classification systems are arbitrary and artificial. The systems are man-made and tailored to suit our purposes. The life and structure of a bacterium is not changed if we place it in the protist kingdom instead of the animal kingdom. Systems of classification change in order that they may better reflect current knowledge.

2. One job of a taxonomist is to name living organisms. What information besides the name can he give us through his system of classification?

Some organisms are very difficult to classify - they simply do not fit into any scheme of classification. This fact doesn't make the classification system worthless. It does show that we do not know everything about every plant and animal. After all

of the organisms are separated into kingdoms, the members of one kingdom are sorted into smaller groups called phyla (singular: phylum). This sorting may result in a different number of phyla for each kingdom. Further sortings provide class, order, family, genus, and species levels.



3. Which two animals are more closely related: (a) the two which are in the same genus (b) the two which are in the same family? Explain your choice.

At the top of our list, the only thing that all the organisms have in common is life. As we read down through the levels, we find that the organisms included in any given group are more and more alike. At the bottom of our list, we find that all of the individuals in a species group are similar in a great many ways. Members of the same species are so closely related that they can mate and produce fertile offspring. In fact, the ability to produce fertile offspring is the definition of the species level.

4. The very tasty Dungeness crab is classified as follows:

Kingdom	Animalia
Phylum	Arthropoda
Class	Crustacea
Order	Decapoda
Family	Cancridae
Genus	<u>Cancer</u>
Species	<u>magister</u>



Another crab was found to be able to mate and produce fertile offspring with the Dungeness crab.

To what genus and species must this other crab belong?

Biologists name plants and animals using a binomial system. "Binomial" means "two names". For example, the scientific name for the Right Whale is Balaena glacialis (scientific names are always in italics or underlined). Balaena, which refers to the baleen plates used to filter out whale food, is the name of the genus to which the Right Whale belongs. Glacialis is the species name for the Right Whale. The scientific name, then, is made up of the genus name and the species name. A scientific name tells us something about the relationships of the organism in question.



5. From the species name, where would you guess the Right Whale lives?

In the following activity you will have an opportunity to observe marine animals and to classify them using the list of phyla provided. If conditions permit, you will be separating animals you have collected. As you group the animals into phyla, remember that the list given is not complete and that other taxonomists might have different classifications. Nevertheless, you will be able to sort the animals into meaningful groups using the list provided. Common names and pictures of some representative animals from each phylum are listed. You may also wish to refer to reference books to confirm your choices.

Materials:

Marine Specimens
Reference books
Labels

Procedures:

1. Classification of the animals will be based on their external anatomy. You will be studying the larger animals which can be seen with the unaided eye. Microscopic forms are considered in other labs. Roughly sort the specimens according to features which are alike or dissimilar. After this rough sorting is done, see how many animals can be grouped by phyla. Take advantage of the human resource materials first -- individual knowledge. For example, someone may have an extensive collection of seashells; another may know the names of many species of fish. After this rough sorting, work in groups of "specialists" -- shell specialists, fish specialists, "worm" specialists, etc., and begin the classification of the specimens in detail.
2. After identification, every identified specimen should be properly labeled. A suggested label form is shown below. A 3" x 5" index card should also be made for each species and maintained in a separate card file.

Suggested Label Form

Scientific name -

Common name -

Family -

Habitat -

Locale -

Description -

Date -

Collector -

Summary of Marine Phyla

The following list will be helpful in the identification of your specimens. The classification scheme used here may not completely agree with those found in other reference books you use. This general outline was suggested by Storer and Usinger in General Zoology and is also based upon Invertebrate Zoology by Barnes, Crustaceans by Waldo Schmitt and Field Book of Seashore Life by Miner. Use the following scheme unless your teacher recommends an alternative.

PhylumCharacteristics

1. Protozoa

Red Tide

Noctiluca-"night light"

Foraminifera-

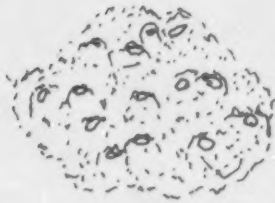
(Globigerina)

Radiolarians

Microscopic: Single isolated cells or colonial forms. Each group has specialized way of moving. Amoeboid movement, whiplike organs or cilia.



II. Porifera Sponges

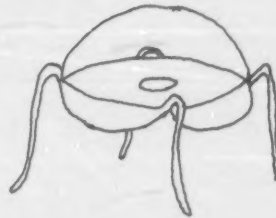


Body cylindrical, branching or irregular. Skeleton of spicules or sponging (see lab exercise on sponge spiculation). Body has many small pores and one or more large openings.

III. Coelenterata

Stinging coral
Portuguese man-of-war
Common jellyfish
Stony and other coral
Sea-pens, sea pansies

Body sack-like -- interior of body functions as a digestive sac. Luminescence common. All species have stinging cells (nematocysts). Live in wide variety of habitats. See lab exercise "Stinging Cells".



IV. Ctenophora

Comb-jellies

Comb plates for locomotion. Only one species with nematocysts. Radially symmetrical. Usually transparent.



V. Platyhelminthes

Flat, soft worms without segments.

Cestodes (Tapeworms)
 Trematods (mostly parasitic)
 Flatworms
 Turbellaria, Bdelloura
 Polyclods



VI. Nemertinia

Ribbon-worms

Flattened, elongated worms.
 Outer surface covered with
 cilia. Have proboscis to
 capture prey. Wide marine
 distribution.



VII. Rotifera

Rotifers

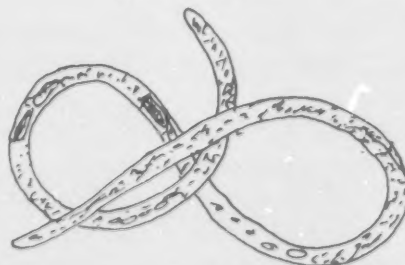
The wheel-animals



VIII. Nematoda

Nematod worms;
 hairworms

Marine forms abundant; free-
 living and parasitic. Found in
 flesh of fish and in marine
 plants.



IX. Bryozoa
Moss Animals

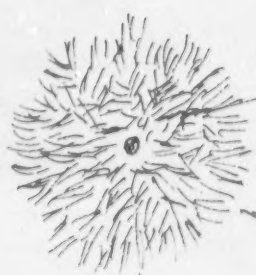


Ancient animals. Many look like seaweeds, some resemble coral.



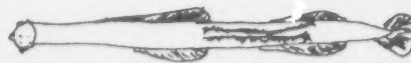
X. Echinodermata
Starfishes
Brittle stars
Sea urchins
Sand dollars
Sea-lilies
Sea cucumbers

Symmetry radial in adults; tube feet projecting ventral part of arms; body covered with delicate epidermis over mesodermal endoskeleton; which often has spines. Entirely marine.



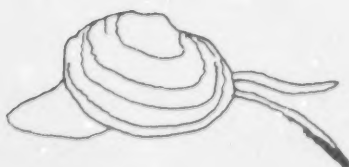
XI. Chaetognatha
Arrow-worms

20 - 70 mm long; arrow-shaped; transparent.



XII. Mollusca
snails, bivalves
(clams, oyster,
scallops), chitons,
octopuses, squid

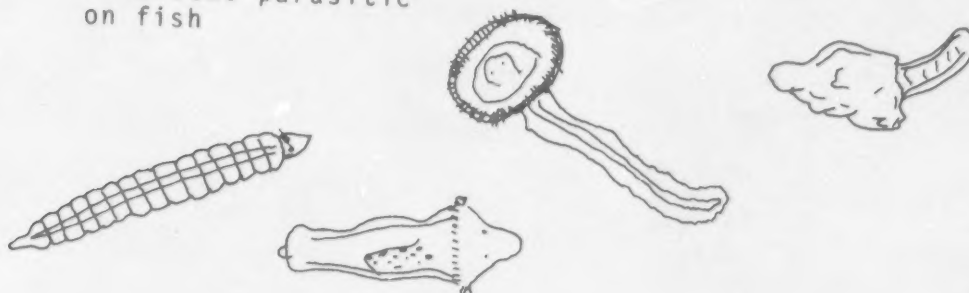
About 80,000 species; most with shells, body soft.



XIII. Annelida

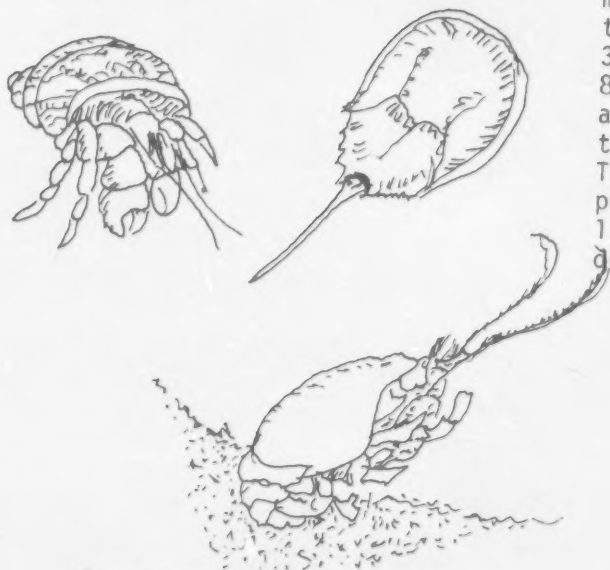
The class Polychaeta are marine: Bristle-worms, tan-worms, etc. Earth-worms, land and fresh-water Leeches, marine, fresh-water, land some parasitic on fish

Segmented worms, setae for locomotion. There are few marine Oligochaetes (earth-worms). Polychaete worms (bristle-worms) make up most of the marine forms.



XIV. Arthropoda.

Crustaceans vary in size from microscopic planktonic forms to lobsters 3 ft. long weighing 35 lbs. Of the approximately 80,000 species of arthropods, about 28,000 species belong to the class Crustacea. There are free-living and parasitic forms. Crustacea larva have many shapes and do not resemble adult forms.



Crustaceans
Lobsters, crabs, water fleas
Copepods, barnacles

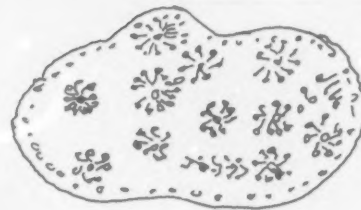
XV. Chordata

- A. Acrania
 Tongue worms
 Tunicates
 Ascidians
 Lancelets
- B. Vertebrates
 Cyclostomes
 Sharks, skates, rays
 Fishes-bony
 Birds
 Reptiles
 Mammals

Possess notochord

No cranium, jaws or vertebrae.
 These chordates are all
 marine, and small in size.
 Some forms are found in all
 oceans.

Have brain enclosed in
 cranium. Typical body: head,
 neck, trunk, tail. None of
 this group strictly parasitic.



BIOLOGICAL FACTORS:

The Sponges - Phylum Porifera

TEACHER BACKGROUND - Rub-a-Dub-Dub

The Phylum Porifera contains the sponges, which are the simplest of multicellular organisms. In fact, there is some debate as to whether sponges are truly individuals or are colonies of single cells tightly associated. The body of a typical sponge consists of loosely aggregated cells organized into poorly defined tissues without organs. There is no mouth or digestive tract in sponges. Instead, the body is covered with small pores (ostia) through which water bearing food enters and fewer large holes (oscula) through which water leaves the animal. As the water passes through the sponge, it travels through a system of canals of varying complexity which are lined with peculiar flagellated cells called collar cells (choanocytes).

The choanocytes, which strongly resemble a group of one-celled animals and thus suggest that sponges may have evolved from them, keep the water moving and extract the food from the water. Amoeba-like cells (amoebocytes) travel about in the sponge's body wall carrying food, producing spicules (tiny needle-like structures which support the animal's body) and carrying out sexual reproduction.

Reproduction in sponges occurs commonly by both asexual and sexual means. A small fragment of sponge will often grow a new individual, and some sponges, when completely torn apart (as for example, when forced through fine meshed silk so that the cells are separated), will reform themselves into complete individuals. Many sponges also reproduce by budding. In sexual reproduction, certain of the amoebocytes form eggs and sperm - usually at different times within the same individual - and fertilization of ova occurs by sperm of another sponge.

Classification of sponges is difficult. The shape of a given sponge is so variable that no system of classification based upon appearance has been very satisfactory. Today, sponges are classified largely by the kinds of spicules present in the body wall. These structures, which serve to give the body skeletal support, are constant in form in a given species but are sufficiently variable that different species can be distinguished by them.

"Rub-a-Dub-Dub" introduces your students to sponge classification using spicules as a guide. The major classes of sponges and the principal types of spicules are outlined in the introductory text accompanying the student activity.

The variety which exists within the sponges should be demonstrated through samples of live or preserved specimens and/or through the use of films or similar audio-visual aids. Sponges may be collected from the intertidal or subtidal areas. Some sponges, especially the encrusting varieties, are easily overlooked. Use your keen powers of observation to discover these members of the sponge family. If a subtidal sponge taken from underwater is to be kept alive, you must be certain not to expose the animal to the air since chambers of the sponge's body fill with air and soon kill the specimen. The best collecting procedure is first to place the container under water and then gently introduce the sponge, keeping it immersed at all times. Intertidal sponges need not be so carefully handled since they are adapted to long periods of exposure. Sponges of various types may also be obtained from biological supply houses.

Duplicate the activity pages. One set is recommended per student. This activity may be performed individually or in small groups. The introductory material and questions may be assigned as homework, to be completed prior to beginning the actual laboratory work. Bleach and acetic acid are materials which can damage skin and clothing. Caution your students to use extra care and to wipe up any spills immediately. Two variations are presented for the preparation of sponge spicules; use the one most convenient for you. Circulate through the lab as the experiment is being performed to be certain that your students are having success in viewing the spicules. Since sponge spicules are transparent, it is sometimes helpful to reduce the illumination on the microscope for better viewing. Upon completion of the activity, plan to allow time for a discussion of the experimental results and to provide answers for the questions.

KEY

Text Questions

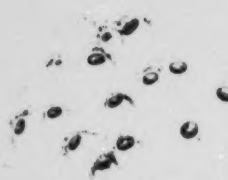
1. Water is moved through the incurrent pores and out the osculum by the action of the whip-like flagella of the collar cells.
2. The sponge can lead a sessile existence because it moves its environment through itself. By moving water through its body the sponge obtains the food and oxygen it needs for survival. The adaptations include the collar cells and their coordinated flagella beating action.
3. From the outside in, the structures that comprise the body wall of the sponge are:
epidermis → jelly-like layer with spicules → the collar cells
4. Since each species of sponge has peculiar shaped spicules, the spicules are useful in the classification of sponges.

Analysis and Interpretation

1. The answer depends upon experimental results.
2. Single species of sponge do not produce both lime and glass spicules. If both were found, it is possible that the sample was contaminated or that portions of two sponges were mixed. These results may also reflect an error in observation. Capillary action by the acetic acid sometimes sweeps the spicules out of the field of vision. To the untrained observer, the spicules may seem to have "dissolved."
3. Polly should prepare spicule suspensions from each of the two sponges and examine them microscopically. If the spicules are the same, the sponges belong to the same species.
4. Spicules form the supporting, skeletal structure of the sponge.

KEY WORDS

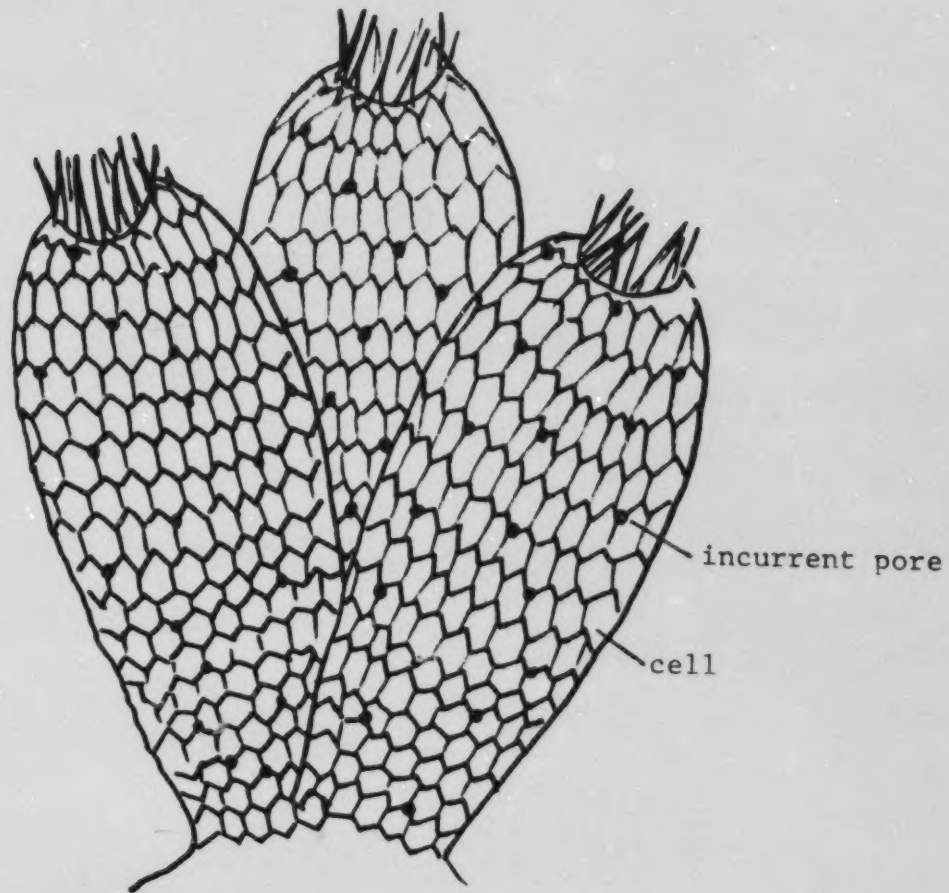
acetic acid
adaptations
amoebocytes
Calcarea
calcium carbonate
choanocytes
collar cells
corrosive
Demospongiae
epidermis
flagella
Hexactinellida
incurrent pores
lime
megascleres
microscleres
monoaxon
multicellular
osculum
pipette
polyaxon
Porifera
sessile
silica
spicules
sponges
spongin
substrate
tetraxon
triaxon

RUB-A-DUB-DUB

Wash the car. Wash the windows. Wash the floor. What are you doing to that poor sponge, anyway? Poor sponge? That washing aid that you're using, if you're lucky enough to have a true sponge, is all that is left of a marine animal.

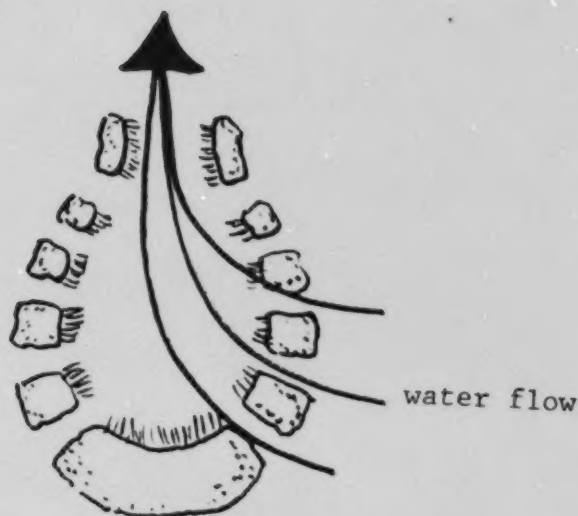
Sponges are strange creatures and not at all like most of the animals with which we are familiar. They can be almost any color, from white and gray to any shade of red or yellow to purple and black. They have no head, body, arms, legs, or any other obvious structures that we generally associate with animals. Some sponges live singly. Others live in crowded colonies that form a crustlike layer over rock surfaces. Individual sponges can be as small as a centimeter or as large as two meters across.

Our washing sponge certainly doesn't look alive. In fact, it isn't. The "sponge" that most of us think about when we hear the word is really only the skeleton of the sponge animal. The skeleton of a living sponge would be surrounded with cells. The body plan of a sponge is simple. Sponges are considered to have the lowest multicellular organization of all the animals. This distinction elevates sponges to just one step above the one called protozoans.



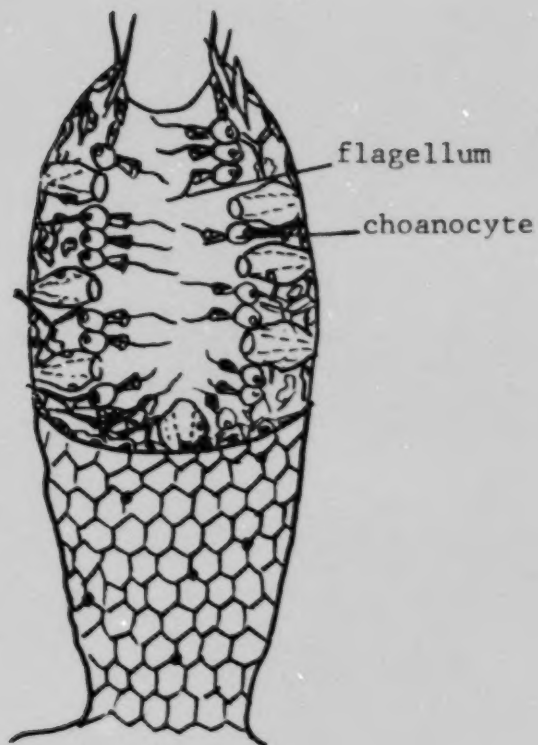
A LIVING SPONGE

Let's examine a living sponge. A close look reveals that the sponge is covered with many small holes or incurrent pores. The pores explain the name of the phylum to which the sponges belong, Porifera, which means "pore bearing." We also see a larger opening called the osculum (from the Latin for "little mouth"). If we were to place a drop of food coloring near the sponge we would be able to follow the dye as it moved into the incurrent pores and out the osculum.



CROSS SECTION OF SPONGE

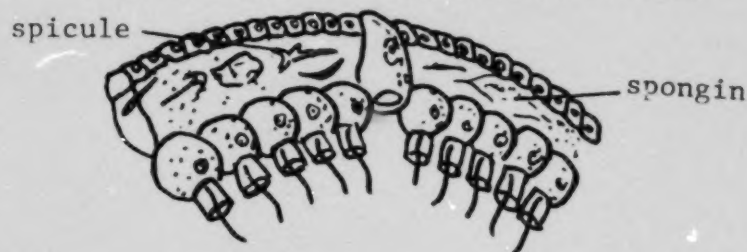
The colored water is moved through the sponge by the movement of whip-like structures (flagella) found on the cells that line the inside of the sponge's body. These cells are shaped somewhat like a goblet and are called collar cells or choanocytes. The current caused by these collar cells moves not only water but also plankton and other small bits of organic matter the sponges use for food. The current also helps supply oxygen to the living cells. Through water movement the sponge draws its food and oxygen to itself. Moving the environment through the sponge keeps the sponge from having to move through the environment. The adult sponge, therefore, can and does spend its life permanently attached by its base to a rock or shell or some similar substrate. The sponge is sessile, or relatively non-moving.



SPONGE CELLS

1. How is water moved through the sponge?
2. What adaptations (special structures or behavior) allow the sponge to lead a sessile existence?

A simple sponge has a hollow body as shown in the figure above. The body wall is formed of two layers of cells separated by a layer of jelly-like material. The outer layer or epidermis protects the sponge. The inner layer contains the collar cells. The jelly layer is a mixture of loose cells, spicules and/or spongin. The spicules are noncellular skeletal structures that help support the sponge's body. Spongin is a tough, fibrous protein material that also helps to support the sponge.



CROSS SECTION

3. From the outside in, what structures comprise the body wall of the sponge?

Spicules are secreted by living cells. They are small rods composed of either lime (calcium carbonate) or glass (silica). The spicules come in a variety of shapes and sizes. Each species of sponge has its own special combination of spicules. Like a fingerprint, these combinations may be used to identify the species of sponge.



SPONGE SPICULES

Biologists have divided spicules into four basic shapes:

1. single axis or straight spicule (monoaxon) which may be curved or club shaped on one end,
2. three pronged or multiple of three spicule (triazon),
3. four pronged spicule (tetraxon) and
4. many pronged spicule (polyaxon).

4. How are spicules useful to biologists?

Spicules are secreted in the sponge by small amoeba-like cells called amoebocytes. These amoebocytes also distribute digested food and oxygen to other cells as they wander through the jelly-like layer. Often sponges produce two types of spicules. The large spicules are called megascleres and the smaller spicules of a different design are called microscleres.

In the following activity you will have an opportunity to examine sponge spicules and use them to identify the sponges from which they came.

Materials:

various sponge animals
bleach solution (50% commercial bleach/
50% water)
dilute acetic acid (5 - 10%)
small test tube or depression slide
Pasteur pipette or medicine dropper
microscope slides and coverslips
forceps
compound microscope

Procedure:

1. Use your forceps to obtain a small piece of sponge (about 2 mm long and as wide as the tip of your forceps). Place the sponge in the bottom of your test tube.

OR

Use your forceps to obtain a small piece of sponge (about 1 mm long and as wide as the tip of your forceps). Place the sponge in the well in your depression slide.

2. Cover the section of sponge with bleach solution (2 to 3 drops for the test tube; 1 drop for the depression slide) to dissolve away the sponge tissue.

3. Allow the tissue to dissolve completely, about two minutes.
4. Use the Pasteur pipette or medicine dropper to remove a small amount (1 to 2 drops) of the dissolved material and place it on a clean slide and cover with a cover slip.
5. Examine the preparation under the compound microscope. You should not require magnification greater than 100x. DO NOT use the high power objective since bleach is corrosive.
6. Locate and observe both the megasclere and the much smaller microsclere.
7. In the space below, make a drawing of the spicules you observe from this sponge.
8. Use the "Types of Sponge Spicules" drawing to find names for the spicules you observed. For Pacific Northwest sponges, find the scientific name by using the "Spicule Guide to Some Common Northwest Sponges." Record your data on the following page.

Type of Megasclere _____

Type of Microsclere _____

Scientific Name _____

9. Carefully introduce a drop of dilute acetic acid at the edge of the cover slip.
10. Use the microscope to observe the spicules for any evidence of bubbling. Dilute acid will dissolve spicules composed of lime (calcium carbonate, CaCO_3) evidenced by bubbling, but will not dissolve spicules composed of glass (silica, SiO_2). Record the composition of your spicules.

Spicule composition _____

11. Sponges are usually grouped according to the type of spicules into three classes:
 Class 1: Calcarea (Calcispongiae) Spicules composed principally of calcium, are monaxon or 3 or 4 branched,
 Class 2: Hexactinellida (Hyalospongiae) Spicules composed principally of silica, are 6-rayed,
 Class 3: Demospongiae (Siliceous) Spicules or horny fibers or both are present. If spicules of silica are present in an intertidal form, the sponge probably belongs to this class since there are no

intertidal hexactinellids present in the Puget Sound region. Spicules, if present, are never 6-rayed.

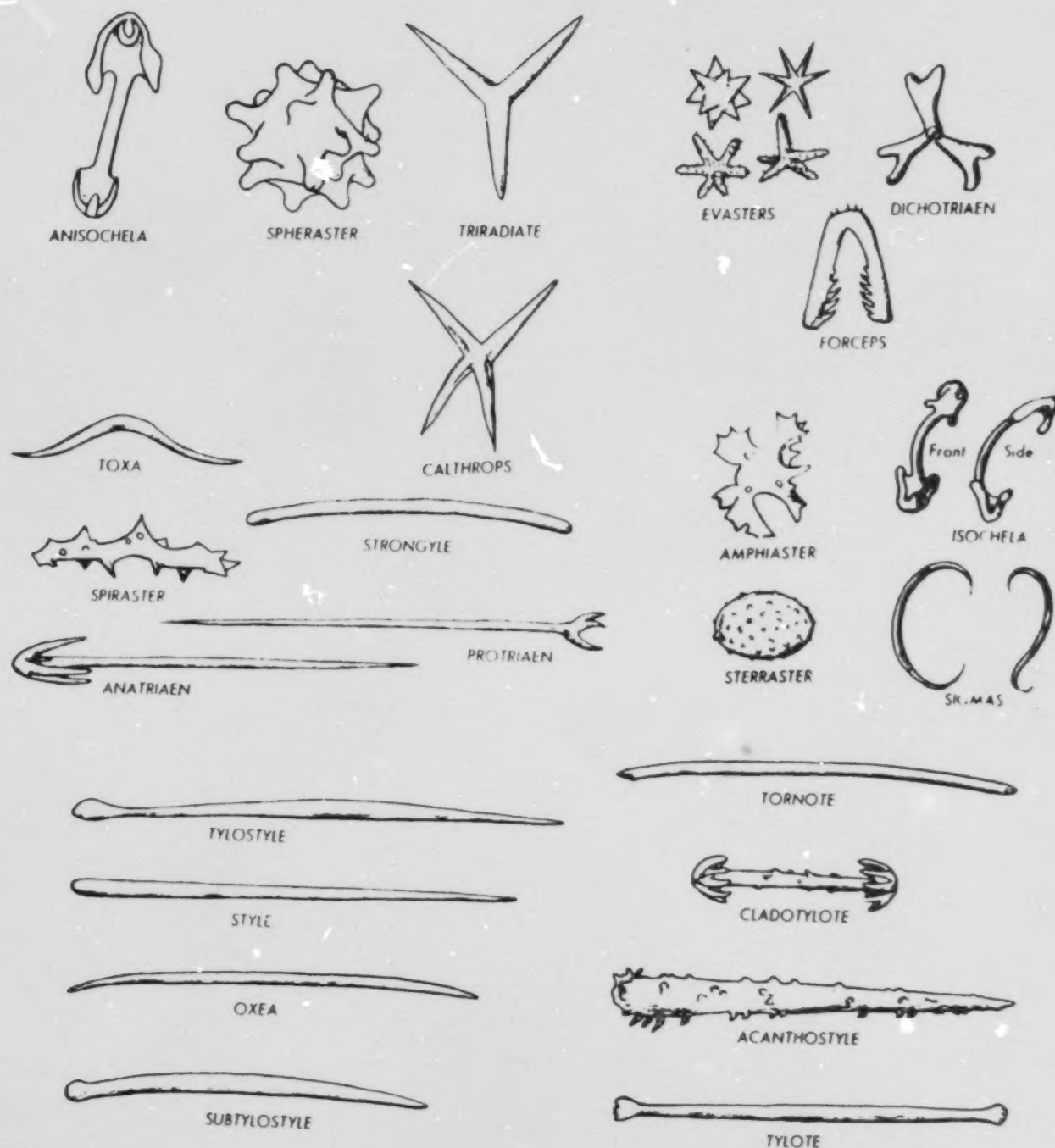
Use this information to determine the class of the sponge from which you obtained spicules.

The sponge belongs to Class _____ because

Repeat the above steps for as many sponges as you can in the time provided.

Analysis and Interpretation:

1. Which type of spicule (monoaxon, etc.) was most common?
2. Did any of your spicule suspensions contain both lime and glass spicules? If so, how might you account for this observation?
3. Polly Porifera found two similar looking sponges on her trip to the seashore. How could she determine if the two sponges belonged to the same species?



TYPES OF SPONGE SPICULES

A SPICULE GUIDE TO SOME COMMON NORTHWEST SPONGES

Sponges are in such taxonomic confusion that the following list is given only with great trepidation. Take it with much salt, and it may prove slightly useful. See Figure 10 for illustrations of the spicules indicated.

<i>Sponge</i>	<i>Large Spicules</i>	<i>Small Spicules</i>
1. <i>Biemna</i> sp.	Smooth styles	Arcuate sigmas
2. <i>Poecillastra</i> sp.	Oxeas and calthrops	
3. <i>Iophon</i> sp.	Spiny styles	Anisochelas
4. <i>Craniella</i> sp.	Anatriaenes and protriaenes	
5. <i>Syringella</i> sp.	Elongate styles are the only spicules present	
6. <i>Esperiopsis</i> sp.	Subtylostyles	Chelas
7. <i>Ophlitaspongia</i> sp.	Subtylostyles	Toxas
8. <i>Plocamia</i> sp.	Subtylostyles tylotes	Toxas and chelas
9. <i>Isociona</i> sp.	Spiny styles and spiny tylotes	
10. <i>Tedania</i> sp.	Smooth tylotes and smooth subtylostyles	
11. <i>Microciona</i> sp.	Smooth styles and smooth subtylostyles	Small chelas and toxas
12. <i>Aplysilla</i> sp.	No spicules present	
13. <i>Halichondria</i> sp.	Oxeas are the only spicules and they are scattered in profusion	
14. <i>Acarnus</i> sp.	Styles and cladotylotes	
15. <i>Choanites</i> sp.	See text description (Fig. 4)	
16. <i>Cliona</i> sp.	See text description (Fig. 5)	
17. <i>Haliclona</i> sp.	Oxeas arranged in trian- gular patterns are the only spicules. See text description. (Fig. 8)	
18. <i>Leucosolenia</i> sp.	Triaxons. See text description. (Fig. 3)	Isochelas and sigmas
19. <i>Scypha</i> sp.	Triaxons	
20. <i>Lissodendoryx</i> sp.	Spiny styles with spines along length. See text description. (Fig. 6)	Large anisochelas
21. <i>Mycale</i> sp.	Smooth styles. See text description. (Fig. 7)	Isochelas and sigmas
22. <i>Myxilla</i> sp.	Spiny styles with spines at one end. See text description.	
23. <i>Polymastia</i> sp.	See text description. (Fig. 9)	

4. While spicules are useful to biologists as an aid to identification, what is their role in the life of the sponge?

TEACHER BACKGROUND - "Who's Living Here?"

"Who's Living Here?" introduces your students to one of the important roles of sponges in the marine environment....that of providing shelter for a horde of creatures. The material builds upon the concepts taught in "Rub-a-Dub-Dub."

Large sponges are preferred for this activity. Specimens may be collected one day, enclosed in strong plastic bags, stored in a refrigerator overnight and used the next day. Sponges decompose rapidly, so it is important to use them promptly. Living sponges may also be purchased from biological supply houses. Large sponges tend to have correspondingly large symbionts. Small sponges may be assigned to individual students or groups. Large sponges should be divided among several groups or the entire class. Provide any reference materials you may have which will aid in the identification of the resident creatures.

Wet weights of organisms are somewhat difficult to standardize. It is suggested that the organism be placed briefly on blotter paper or towelling before it is weighed. Be sure the balances are cleaned after use, as salt water is very corrosive.

Duplicate the activity pages. One set is recommended per student. This exercise is best done in small groups, although if the materials and equipment allow, it may be performed by individual students. Some students may need a hand with the slicing. Watch for those that do. Plan to allot time for a discussion of the role of the sponge as an apartment house of the sea when you review the experimental results and provide answers for the questions in the "Analysis and Interpretation" section.

KEY

- 1., 2., 3., 4. The answer depends upon the experimental results. Be aware that percentage calculations tend to be difficult for many students. The examples provided may not be sufficient. Be prepared to offer any assistance necessary.
5. If sponges were over-harvested, most likely the populations of the organisms that live within the sponges would decrease since their habitat was removed. The populations of the organisms that depend upon the organisms that live within the sponges would also decrease since their food supply would be reduced.
6. We can say that all life within the sea is interconnected because whatever affects one species affects all species to a greater or lesser degree. This is an important concept to emphasize at a time when man's actions with the sea tend to have dramatic, and often negative, impacts upon marine life.

KEY WORDS

ascon
classify
commensal
compute
interconnected
leucon
mutualistic
over-harvested
percent
populations
sponges
sycon
symbiotic

WHO'S LIVING HERE?

Sponges enclose a great deal of space. They are primarily a bag with a system of holes, chambers and compartments. In their 500 million year history, sponges have evolved three basic canal systems which biologists call: ascon, sycon and leucon. The three body types are shown in the three sponge cross sections shown below.



Ascon



Sycon



Leucon

SPONGE CROSS SECTIONS

The enclosed space within the sponge offers a large number of hiding and living places for smaller animals. The relationships that exist between the sponge and the organisms within are of many different types. Some of the residents are commensal, meaning they benefit and the sponge is not harmed. Other residents exist in a mutualistic relationship, where both the resident and the sponge are benefitted by the association.

The symbiotic relationships can be very interesting indeed. One particular glass sponge of the class Hexactinellida, Venus'-flower-basket, displays an interesting commensal relationship with certain species of shrimp.



VENUS'-FLOWER-BASKET

A young male and a young female shrimp enter the cavity of the sponge and, after growth, are unable to escape through the sieve plate covering the osculum.

Their entire life is spent in the sponge prison, where they feed on plankton brought in by the sponge's water currents. The sponge with its imprisoned shrimp formerly was used in Japan as a wedding present, symbolizing the idea "till death us do part."

Sponges are the apartment houses of the sea. In the following activity you will have an opportunity to discover which types of organisms are residents of sponges.

Materials:

dissecting kits
sorting jars
dissecting microscope
balance
ruler
identification keys
sponges

Procedure:

1. Obtain a sponge or a piece of a sponge.
2. Using the balance, weigh the sponge.
Record the weight.

Sponge weight _____

3. Carefully slice off a thin section of sponge tissue. Examine the slice for animal life.
4. Sort out the creatures according to phyla using "A Summary of Marine Animal Phyla."
Use additional references to further

2. Compute the percent of total population for each species by numbers.

(Hint: This is easy -

$$\begin{array}{l} \text{The percent contributed} \\ \text{by species A} \end{array} = \frac{\text{number of species A}}{\text{total number of individuals}} \times 100$$

3. Compute the percent of total population for each species by weight. (Use the same technique you used for numbers in problem 2 above.)

4. Compute the percent of total weight contributed by the residents.

(This is easy, too -

$$\begin{array}{l} \% \text{ weight contributed} \\ \text{by residents} \end{array} = \frac{\text{total weight of residents}}{\text{total weight of sponge}} \times 100$$

classify the animals. Keep the sorted specimens.

Record your results.

Name

Number found

5. Repeat steps 3 and 4 until the entire sponge has been dissected and all of the inhabitants removed and sorted.
6. Use the balance to weigh each group of sorted animals. Record your results.

Name

Weight

Analysis and Interpretation:

1. What was the total number of individuals found within your sponge?

5. If the sponges were over-harvested, what would happen to the populations of the organisms that depend upon the organisms that live within the sponges?

6. How can we say that all of the life of the sea is interconnected?

TEACHER BACKGROUND - One From Many

"One From Many" duplicates the classic experiment of H. V. Wilson which demonstrated the power of reassociation in sponges. The cell layers of the sponge function in loose concert. Different cells have become specialized for different functions, yet tend to act somewhat independently of each other. The paradox of multicellular animals has a slightly different twist within the sponges. The paradox notes that mitotic cell division produces two identical daughter cells yet multicellular organisms are not simple masses of identical cells. How does differentiation occur? In the sponges, the cells retain many of their original properties and can function more or less independently of the organism. The cells are not highly differentiated. The sponge seems to be a group of animals that bridges the gap between single celled organisms and multicelled organisms.

Microciona sps. may be collected at the beach or ordered from biological supply houses. A single 1 gram fragment will provide enough suspension for a whole class, so great quantities are not required. The common pecten sponges, Mycale adhaerens and Myxilla incrustans, are also suitable specimens for this investigation. These encrusting sponges are almost invariably found growing on the upper valve or pecten scallops.

Caution your students to add the sponge suspension to the slide by gently placing the tip of the Pasteur pipette on or slightly above the slide. The suspension is slightly more dense and will tend to form a drop on the slide if the water is not agitated. Care is also required in the transport of the finished finger bowl preparations.

Duplicate the activity pages. One set is recommended per student. This activity is best performed by small groups of students. If you have no refrigeration facilities, you may elect to omit the finger bowls stored at 4⁰ C. (Better, however, is to solicit a donation of a used refrigerator from your community. It is surprising how many working refrigerators are available for the polite asking.) You may elect to have some groups set-up and examine the room temperature preparations while others do the refrigerated set-up. The data can then be pooled and the questions answered. It is also possible for different groups to do the different dilutions and then pool their data upon completion. Choose whichever technique you feel will

work best with your class. Good technique is required for good results. Anticipate any potential problems which might be encountered with your class and plan accordingly. Allot some time at the conclusion of the experiment for a discussion of the techniques and the results.

KEY

- 1, 2, 3. Answers depend upon experimental results. In general, more clumps are found at the higher dilutions and temperatures.
- 4, 5. The answers depend upon the experimental results obtained. In general, larger clumps are found at the higher dilutions and temperatures. Commercial sponge growers might use the technique to increase the number of sponges they have to grow. Artificial propagation might also be useful in "seeding" sponges into new areas.
5. The answer to this question is not simple: a case can be made for either theory. The disassociated cells certainly behave like independent individuals; a fact that supports the theory that sponges are a group of single celled animals living in one place at one time. The individual cells do, however, reaggregate and form new sponge animals, a fact that seems to support the idea that the cells require the presence of others in a division of labor scheme. While the experimental observations do not answer the debate, they do show the tremendous reassociative powers of the sponge.

KEY WORDS

aggregation

association

dilution

Microciona sps.

silk bolting cloth

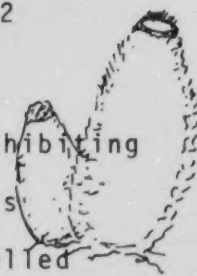
sponges

suspension

theory

ONE FROM MANY

Sponges are the simplest of multicellular organisms, exhibiting little coordination between cells. In fact, some biologists view sponges more as an association of individual single celled organisms rather than as a single, entire animal. In the following exercise you will have an opportunity to look into the question yourself. Are sponges single animals or a group of single celled animals living in the same place at the same time?



Materials:

Microciona sps. sponge

Number 21 silk bolting cloth

seawater (4⁰)

250 ml Griffin beaker (1)

150 ml Griffin beaker (3)

graduated cylinder (100 ml)

4 finger bowls (6 inch) and covers

4 Syracuse watch glass

8 slides

glass marking pen or labels

Pasteur Pipette

thermometer

refrigerator

compound microscope

balance

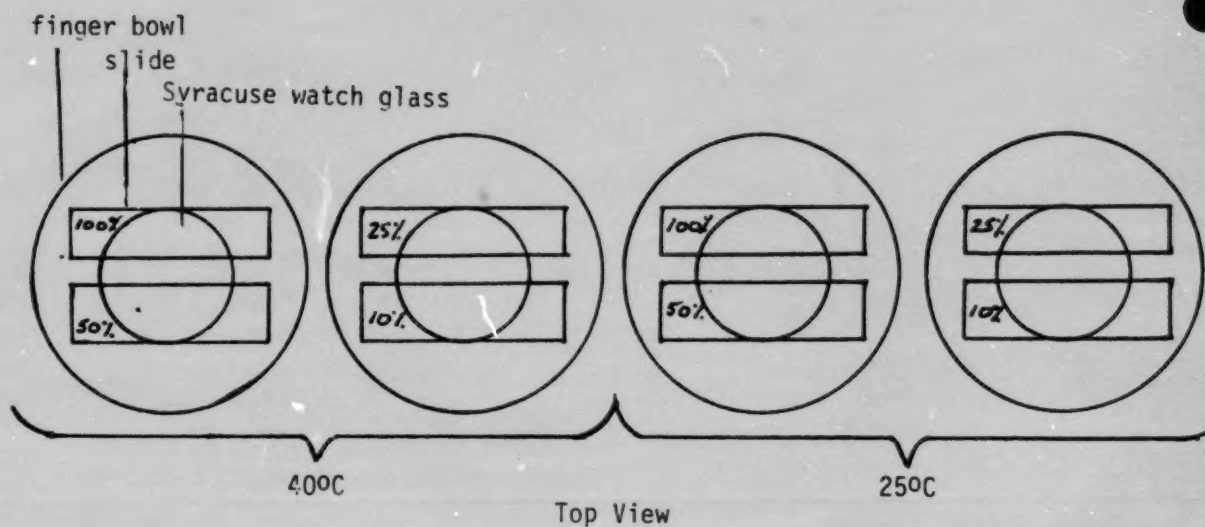
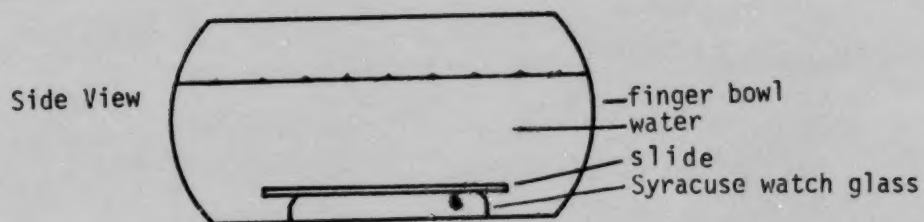
Procedure:

1. Obtain 1 gram of fragments of fresh Microciona sponge.
2. Place 100 ml of cold (approximately 4⁰C) seawater in a 250 ml. beaker.

3. Press the sponge fragments through number 21 standard quality silk bolting cloth into the 100 ml of cold seawater. (Rub sponge against cloth, then rinse through. Repeat until sponge is gone).
4. Use the 100 ml sponge preparation to prepare the following dilutions of sponge suspension and place them in labeled 150 ml Griffin beakers:
 - a. 25 ml sponge suspension + 25 ml seawater (4°) =
50% dilution
 - b. 10 ml sponge suspension + 30 ml seawater (4°C) =
25% dilution
 - c. 10 ml sponge suspension + 90 ml seawater (4°C) =
10% dilution
5. Fill four small (6 inch) finger bowls two thirds full with the cool seawater.
6. Place a Syracuse watch glass on the bottom of each finger bowl.
7. Obtain eight microscope slides. Label two for each of the four dilutions: 100%, 50%, 25% and 10%.

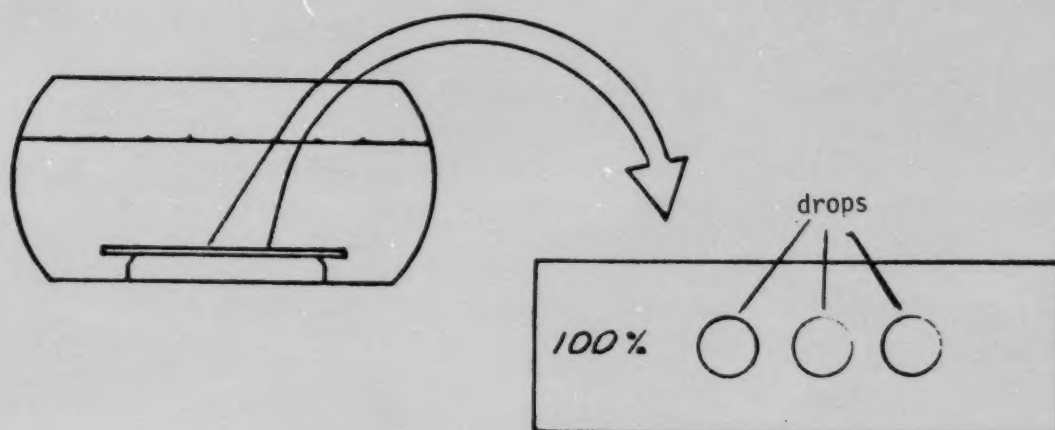
8. Place two slides on each Syracuse watch glass.

A.



9. Use a Pasteur pipette to gently dispense one or two drops of the original suspension onto the center of the slide labeled 100%. Place equal sized drops to the right and left of the center drop. This will give you three samples to watch.

B.



10. Repeat step nine for each of the three dilutions remaining. Be sure to put the dilution on the proper slide.
11. Cover the finger bowls and allow one group to stand undisturbed for twenty four hours at 4°C (refrigerator) and another at room temperature (about 25°C).
12. After 24 hours, gently remove the slides, cover the drops with a coverslip and examine under the microscope. You can prevent the slides from drying out by adding water or not removing them all at once.
13. In the space below, draw and label a sample of each of the eight slide preparations. To make your drawing and counting easier, choose the drop with the largest clumps from the three drops on each slide.

14. Count the aggregates in one field on each slide. Record these figures:

Slide	Number of Aggregates	
	40°C	25°C
100%	_____	_____
50%	_____	_____
25%	_____	_____
10%	_____	_____

15. Estimate the size (in microns) of the largest aggregate found on each slide. Record these estimates:

Slide	Size of Aggregates (microns)	
	40°C	25°C
100%	_____	_____
50%	_____	_____
25%	_____	_____
10%	_____	_____

Analysis and Interpretation:

1. What was the largest aggregation of sponge cells that you found?
2.
 - a. Which slide had the largest number of aggregates?
 - b. What is the relationship between dilution and number of aggregates?
3.
 - a. Which temperature had the largest number of aggregates?
 - b. What is the relationship between temperature and number of aggregates?

Analysis and Interpretation

1. What was the largest aggregation of sponge cells that you found?
2. a. Which slide had the largest number of aggregates?
b. What is the relationship between dilution and number of aggregates?
3. a. Which temperature had the largest number of aggregates?
b. What is the relationship between temperature and number of aggregates?
4. a. Which slide had the largest aggregates?
b. What is the relationship between dilution and size of aggregates?
5. a. Which temperature had the largest aggregates?
b. What is the relationship between temperature and size of aggregates?
6. Each aggregate has the potential for developing into a new sponge. How might a commercial sponge grower use this information to her advantage?

4. a. Which slide had the largest aggregates?
b. What is the relationship between dilution and size of aggregates?
5. a. Which temperature had the largest aggregates?
b. What is the relationship between temperature and size of aggregates?
6. Each aggregate has the potential for developing into a new sponge. How might a commercial sponge grower use this information to her advantage?
7. Does the ability of sponges to reassociate after being broken up support the theory that sponges are single animals or the theory that sponges are a group of single celled animals living in the same place at the same time? Explain your choice.

BIOLOGICAL FACTORS:

The Jellyfish - Phylum Coelenterata

TEACHER BACKGROUND - The Sting

The coelenterates are the lowest forms in the animal kingdom which have cells arranged into definite tissues. Members of the phylum are of two types: (1) the medusa, which is the typical umbrella-like jellyfish form with trailing tentacles; and (2) the polyp, which has a cylindrical body attached at the base, with tentacles at the upper margin encircling the mouth. Many species of coelenterates have within their life cycle both medusae and polyps. This has resulted in much taxonomic confusion.

All coelenterates possess the following characteristics:

1. The body is composed of two layers of cells.
2. Stinging cells (nematocysts) used primarily for food gathering, cover the tentacles and much of the body.
3. The body cavity is a sack with only a mouth opening into it. Waste material is eliminated through this single opening.
4. Tentacles surround the mouth opening.
5. There is no circulatory, excretory, or respiratory system, but a diffuse nervous system under no central control is present.

The coelenterates are grouped into three classes as follows:

CLASS 1. HYDROZOA --THE HYDROIDS.

The body cavity is perfectly smooth and most marine forms are colonial, a great many individuals are associated on the same tree-like stalk. Individuals are so small that they must be inspected under magnification. Reproduction in this class is commonly by alternation of generation (metagenesis) with asexual budding in the polyp stage and sexual reproduction in the free floating jellyfish stage (see accompanying figure). The bulk of the life cycle is spent in the colonial polyp stage.

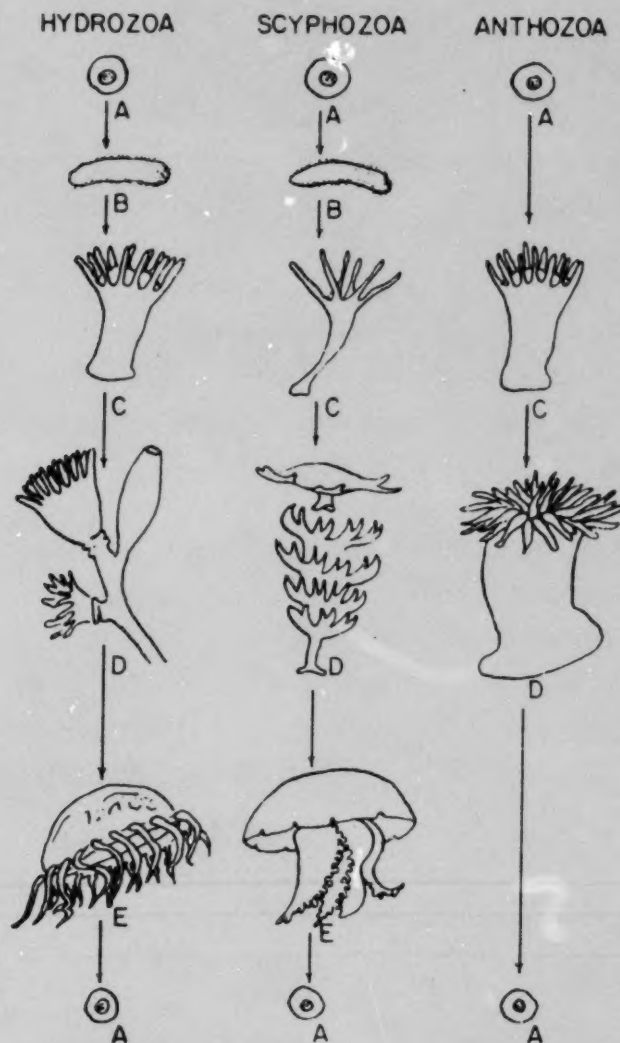
CLASS 2. SCYPHOZOA -- THE TRUE JELLYFISH.

Members of this class spend the bulk of their lives in the free-floating jellyfish stage. Most scyphozoan jellyfish are much larger than the hydrozoans, and although most scyphozoans reproduce by metagenesis, the polyp stage is seldom seen and is usually smaller than that of the hydrozoan.

Hydrozoan medusae always possess a shelf-like membrane (velum) about the inner surface of the "umbrella" while this structure is always lacking in scyphozoan medusae.

CLASS 3. ANTHOZOA, SEA ANEMONES, CORALS, etc.

The body cavity is broken up into a number of "chambers" by vertical septa, and all anthozoa occur only as attached polyps; i.e., there is no medusa stage present in the life cycle. Most intertidal anthozoans in Northwest waters are much larger than are the hydrozoan polyps. If the polyp is large enough to be easily distinguished with the naked eye, it is probably an anthozoan. Most intertidal forms in the Northwest are soft bodied, but occasionally large branching plant-like forms with an inner support of bone-like or wood-like material are found.



Life cycles of the various class of coelenterates. A. Ovum (egg); B. Planula larva; C. Immature Polyps; D. Mature Polyps; E. Medusa After Flora and Fairbanks, The Sound and the Sea.

It is likely that your students will have only limited familiarity with members of the phylum Coelenterata. Use your bulletin boards for displays of pictures of coelenterates, add hearty members to your salt-water tank, and make use of available audio-visual aids to show your students the variety that exists within this group. Duplicate the text and activity pages. One set is recommended per student. The text and vocabulary reviews provide the necessary background material for the laboratory activity "Nematocyst Firing". While the vocabulary review helps reinforce the new vocabulary, you should make an effort in this section (and all of the sections) to incorporate the new vocabulary into your classroom discussions. Provide time for a discussion of the clues and solution of the vocabulary review.

KEY

The key for the vocabulary review is found on a separate page following.

KEY WORDS

Anthozoa
cell
cilia
cnidoblasts
cnidocil
Coelenterata
colonial
digestion
ephyra larvae
epidermal
gastrovascular cavity
glutinants
gonads
Gorgon Medusa
Hydrozoa
larval
medusa
nematocysts
oral arms
organelles

penetrant
polyp
radially symmetrical
scyphistoma
scyphozoa
tentacle
tissue
volvent

KEY - VOCABULARY REVIEW

Jellyfish, sea anemone, corals are all interesting animals. Jellyfish come in a great variety of sizes and colors; from microscopic, clear specimens to the Portuguese Man of War with tentacles several meters in length. Regardless of their size all of the jellyfish are

Z O O P L A N K T O N.
9 3 6 7 4 5 11 8 2 1 10

To learn what this word is, take the following steps: (1) From the list of words given, select the one to fit each definition below and write it in the spaces at the left, starting with the first space and leaving blank all those you do not need to complete the word.

(2) Transfer the circled letters to the appropriate spaces above.

WORDS: medusa penetrants scyphozoa volvents tissue
hydrozoa anthozoa Coelenterata larval cnidoblast
nematocysts sacklike radial polyp tentacle cilia

- | | |
|---|---|
| <u>A</u> <u>N</u> <u>T</u> <u>H</u> <u>Q</u> <u>Z</u> <u>O</u> <u>A</u> _ _ _ _ _ | 1. Sea anemone belong to this class of coelenterates. |
| <u>C</u> <u>N</u> <u>I</u> <u>D</u> <u>O</u> <u>B</u> <u>L</u> <u>A</u> <u>S</u> <u>T</u> _ _ _ _ _ | 2. These specialized cells contain the nematocysts. |
| <u>C</u> <u>Q</u> <u>E</u> <u>L</u> <u>E</u> <u>N</u> <u>T</u> <u>E</u> <u>R</u> <u>A</u> <u>T</u> <u>A</u> _ _ _ _ _ | 3. Members of this phylum are tentacle-bearing radially symmetrical animals which possess stinging cells. |
| <u>Q</u> <u>A</u> <u>R</u> <u>V</u> <u>A</u> <u>L</u> _ _ _ _ _ | 4. During this stage the jellyfish is microscopic and covered with hair-like cilia. |
| <u>M</u> <u>E</u> <u>D</u> <u>U</u> <u>S</u> <u>A</u> _ _ _ _ _ | 5. This umbrella shaped form found among the coelenterates takes its name from Greek mythology. |
| <u>N</u> <u>E</u> <u>M</u> <u>A</u> <u>T</u> <u>Q</u> <u>C</u> <u>Y</u> <u>S</u> <u>T</u> <u>S</u> _ _ _ _ _ | 6. These specialized structures are used to ensnare, harpoon or poison food. |
| <u>Q</u> <u>P</u> <u>O</u> <u>L</u> <u>Y</u> <u>P</u> _ _ _ _ _ | 7. A cylindrical body form, attached at the base, with tentacles encircling the mouth. |
| <u>S</u> <u>A</u> <u>C</u> <u>K</u> <u>L</u> <u>I</u> <u>K</u> <u>E</u> _ _ _ _ _ | 8. The presence of this kind of a body allows the coelenterates to use a much greater range of food sizes than is possible in the sponge. |

S C Y P H O (Z) O A _ _ _

9. Jellyfish belong to this class of coelenterates.

T E (N) T A C L E S _ _ _

10. These projections are found on all coelenterates.

V O L V E (N) T S _ _ _

11. Cnidoblasts of this variety wrap around and ensnare the victim.

THE STING

Jellyfish, sea anemones, corals and microscopic hydras. Very different animals, yet all grouped together in the phylum Coelenterata. What do these animals share that cause biologists to group them within a single phylum?



microscopic hydra



jellyfish



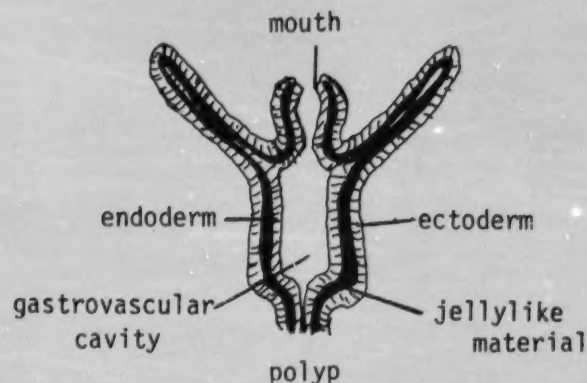
sea anemone



coral

The coelenterates are tentacle-bearing, radially symmetrical animals with a sacklike body composed of two basic cell layers. Radial symmetry is a body design in which the parts radiate from a center as spokes radiate from the hub of a wheel. The sacklike body provides an internal space for digestion (the gastrovascular cavity).

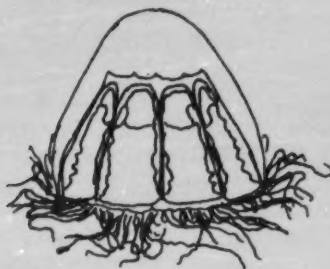
The hollow space opens to the outside at one end to form a mouth. The presence of a mouth and digestive cavity permits the use of a much greater range of food sizes than is possible in the sponges.



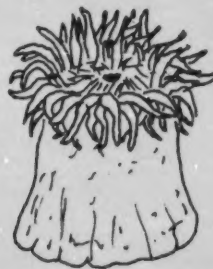
Coelenterates represent an important advance in cellular organization. The protozoa and sponges operate on the cellular level. Coelenterates are at the tissue level of organization. The different kinds of cells present are organized into groups in which all cells have similar structural and functional characteristics. A tissue is a group of similar cells organized to perform a particular function. Coelenterates have specialized epidermal, nervous, digestive and muscular tissues.

Two body forms are found among the members of the coelenterates:

- a. medusa - an umbrella shaped jellyfish form with trailing tentacles



- b. polyp - a cylindrical body, attached at the base, with tentacles at the upper margin encircling the mouth.



The two body forms of the coelenterates are grouped into three classes:

- Class Hydrozoa - the hydroids



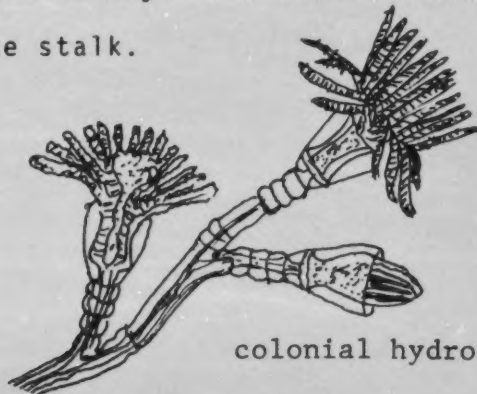
Class Scyphozoa - the true jellyfish



Class Anthozoa - the sea anemones and corals

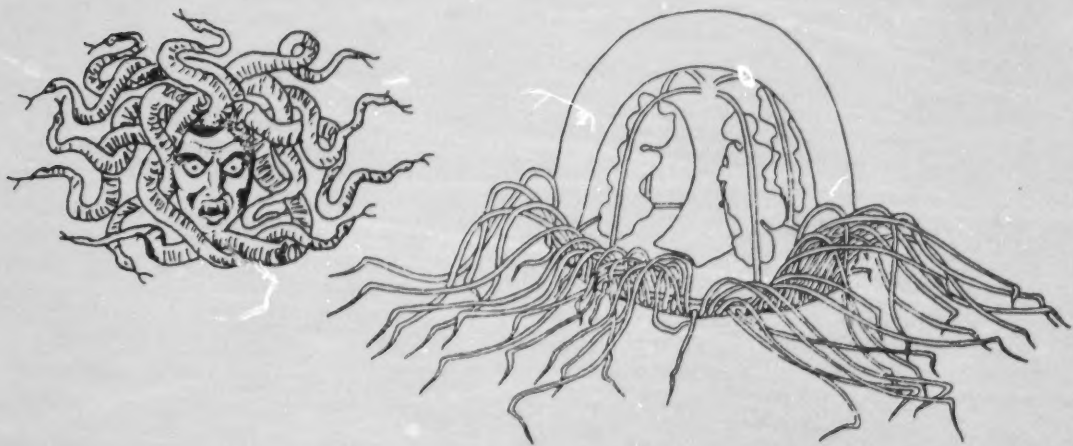


The class Hydrozoa contains a large number of common coelenterates. Because of their small size and excellent camouflage, most people are unaware of the members of this group. Most of the life cycle of the hydrozoans is spent in the polyp stage. Most marine hydrozoans are colonial, a great many individuals are associated on the same tree-like stalk.



colonial hydrozoan

Members of the class Scyphozoa spend most of their lives in the free-floating medusa form. The jellyfish is found in seas from the Arctic to the tropics. These fragile looking umbrellas are able to withstand long sea journeys and much wave battering. The term medusa has its origin in ancient Greece. The Gorgon Medusa of Greek mythology was a woman-monster figure that, instead of hair, had a mass of waving snakes atop her head. The resemblance of the Medusa and the half-round jellyfish, with tentacles streaming snake-like from its edges is very evident.

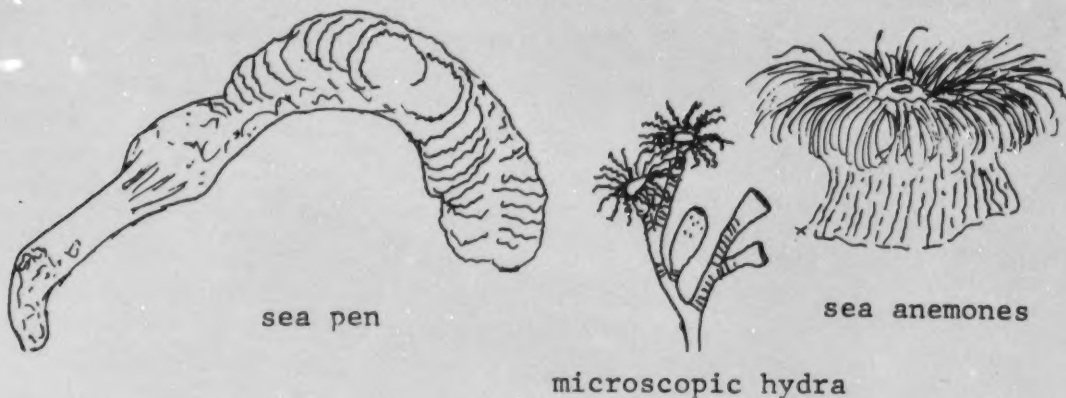


Medusa

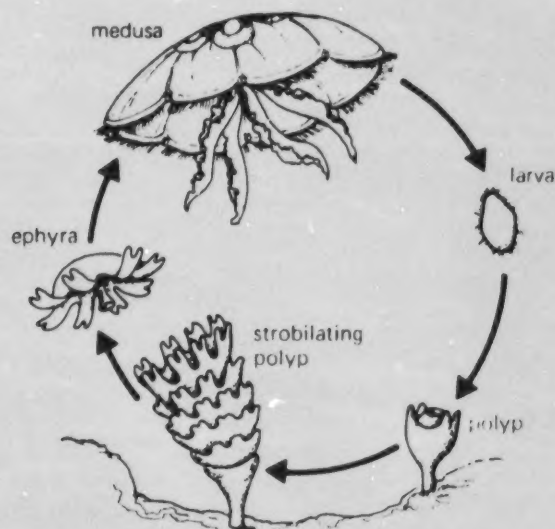
and

medusa

All of the members of the class Anthozoa spend their lives as attached polyps. Most anthozoans found in Northwest waters are much larger than are the hydrozoan polyps. If the polyp is large enough to be easily seen with the naked eye, it is probably an anthozoan. This class includes the coral animals which are found in all seas. Anthozoans have adopted many different forms.



Coelenterates show many different life cycles. The life cycle of a jellyfish can be used to show the general features of the coelenterate life cycle.

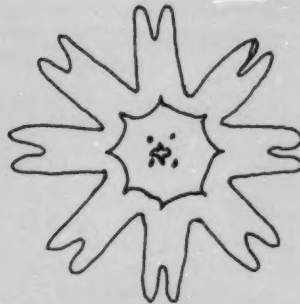


Jellyfish go through three stages of development: larval, polyp, and medusa (mature jellyfish). In most jellyfish, the sexes are separate. The gonads, or primary sex glands, whether male or female, develop in the lining of the gastrovascular cavity. When spawning occurs, the eggs or sperm are released to the outside through the gastrovascular cavity. The eggs generally settle on the oral arms and are fertilized there. Young embryos begin their development on these long arms. They then detach and become microscopic larvae covered with hair-like cilia. The rapid beating of these cilia propel the larvae through the water.



After leaving the protection of the adult, the larva tries to find a home where it can attach and begin the second stage of development (polyp). Rocks, shells, cans or bottles in shallow protected water are all suitable materials, but jellyfish larvae seem to prefer oyster and clam shells.

Once the larva has found a home, it begins the polyp stage. First, (during the scyphistoma period), the body divides into segments: Each segment then develops until it is pinched off as a ephyra larva. This pinching off is called strobilation.



ephyra larva

Ephyra larvae grow to adults and are called medusae. At this third and final stage of development, they are ready to produce eggs and sperm and begin the life cycle again. A jellyfish will normally live three to six months; rarely does its life span exceed a year.

Coelenterates possess special structures, the nematocysts or "stinging cells", which aid them in obtaining food.

These stinging structures are actually organelles of a cell known as a cnidoblast (nid - o - blast). Cnidoblasts differ from species to species. They perform their food-getting or defensive functions in one of three ways:

- a. volvents - which wrap around and ensnare the victim
- b. penetrants - which stick into the victim, like a harpoon or a arrow.
- c. glutinants - which not only penetrate the victim, but also inject a poison.

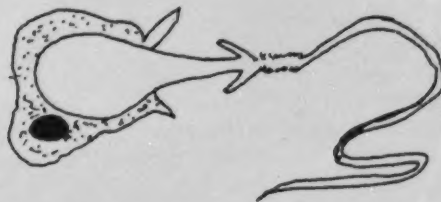
Some biologists consider cnidoblasts to be the most specialized cells in the animal kingdom.



Unfired Nematocyst

As the drawing shows, cnidoblasts are rounded cells with the nucleus near the base. One end of the cell contains a short, bristle-like process called a cnidocil. The cnidocil acts like a trigger and is usually exposed at the surface. The interior of the cell is filled by a capsule containing a coiled, pleated tube. The end of the capsule which is directed outward is covered by a cap or lid.

The firing mechanism is not well understood. It appears that chemical changes occur in the cell membrane that cause an intruding of water and greatly increased pressure. As a result the lid is forced open, the tube turns inside out, and the entire nematocyst explodes to the outside.



Discharged Nematocyst

In the activity that follows you will have a chance to observe nematocyst firing. Since the nematocyst is a delicate structure, you will need to use your best laboratory technique.

THINKING WORDS.

Thinking is at the very heart of everything that you will ever try to learn. Almost all of the thinking you do is performed with words. We must know what words mean and how they are related. The following exercise is designed to help you learn the meanings of important terms from "The Sting" and to help you see the relationships between these words.

Jellyfish, sea anemone, corals are all interesting animals. Jellyfish come in a great variety of sizes and colors; from microscopic, clear specimens to the Portuguese Man of War with tentacles several meters in length. Regardless of their size all of the jellyfish are

9 3 6 7 4 5 11 8 2 1 10

To learn what this word is, take the following steps: (1) From the list of words given, select the one to fit each definition below and write it in the spaces at the left, starting with the first space and leaving blank all those you do not need to complete the word.

(2) Transfer the circled letters to the appropriate spaces above.

WORDS: medusa penetrants scyphozoa volvents tissue
hydrozoa anthozoa Coelenterata larval cnidoblast
nematocysts sacklike radial polyp tentacle cilia

- | | |
|-------------|---|
| _____○_____ | 1. Sea anemone belong to this class of coelenterates. |
| _____○_____ | 2. These specialized cells contain the nematocysts. |
| _____○_____ | 3. Members of this phylum are tentacle-bearing radially symmetrical animals which possess stinging cells. |
| ○_____ | 4. During this stage the jellyfish is microscopic and covered with hair-like cilia. |
| _____○_____ | 5. This umbrella shaped form found among the coelenterates takes its name from Greek mythology. |
| _____○_____ | 6. These specialized structures are used to ensnare, harpoon or poison food. |

- ----- 7. A cylindrical body form, attached
at the base, with tentacles encircling
the mouth.
- ○ ----- 8. The presence of this kind of a body
allows the coelenterates to use a
much greater range of food sizes
than is possible in the sponge.
- ○ ----- 9. Jellyfish belong to this class of
coelenterates.
- ○ ----- 10. These projections are found on all
coelenterates.
- ○ ----- 11. Cnidoblasts of this variety wrap
around and ensnare the victim.

TEACHER BACKGROUND - Nematocyst Firing

One of the most interesting and specialized cells found in the animal kingdom is the cnidoblast or stinging cell possessed by members of the phylum Coelenterata. Nematocysts, discharged from the cnidoblast, are used for anchorage, for defense and for the capture of prey. In this lab your students will have an opportunity to examine the discharge of nematocysts.

The success of this lab is dependent upon the availability of live specimens. One or two specimens of sea anemone (or jellyfish) will provide material for 75 or more students. The animals will remain alive and healthy in a well aerated aquarium in spite of frequent removal of acontia, the threadlike structures used in the following activity. Sea anemones of the genus Metridium have large, easily observed nematocysts.

Duplicate the activity pages. One set is recommended per student. Background material describing nematocysts and coelenterates in general is found in "The Sting". Obtaining the acontia is usually no problem, they appear in great number when the sea anemone is removed from its substrate. Review with your class the techniques used to obtain fluid movement under a cover slip. A small piece of paper toweling or blotter placed on the opposite side of the cover slip can help pull the fluid under the cover slip. Methylene blue may be added to the acetic acid used in order that the fluid movement may be more easily observed. Several observations made on low power do not use cover slips. During these observations, caution your students to use only low power and to be sure to wipe up any spills (both on and off the microscope) of saltwater or chemicals. Nematocyst discharge is dramatic and your students should have little trouble identifying firing. If necessary, review procedures for measuring objects within the field of vision. Plan to provide time for a discussion of the questions found in the body of the activity and in the "Analysis and Interpretation" section. By circulating through the classroom, you can be available to provide aid to your students as they need it.

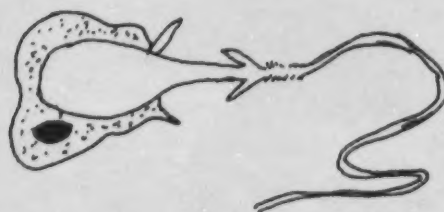
KEY

Questions in Procedure Number:

3. Answers depend upon experimental results. The acetic acid increases the number of nematocysts firing.
5. Answers depend upon experimental results. Mechanical stimulation increases the number of nematocysts firing.
6. Answers depend upon experimental results. Clam juice causes a reduction in the discharge rate but may not stop the firing completely since mechanical stimulation etc. may play a counter-vailing role.
9. Answers depend upon the experimental results. The nematocysts can still fire. Each nematocyst acts independently of others and does not appear to be under the control of any central nervous system. This observation has led nematocysts to be called "independent effectors".
10. Sketches should resemble the following:



Unfired Nematocyst



Discharged Nematocyst

11. The average width of a nematocyst Metridium sp. is about 250 microns. The range, however, is fairly large within a species and between species is tremendous.
12. The length of a discharged thread is about three times the width of the nematocyst or in the case of the acontia of Metridium sp. the length is about 750 microns.

Analysis and Interpretation

1. While the answer depends upon the experimental results, acetic acid, mechanical stimulation, and ketchup all can cause an increase in nematocyst firing.
2. The best conclusion that can be drawn from the experimental results is that certain chemicals seem to have an effect on the rate of discharge of nematocysts.
3. From the observations made in step 5, one might conclude that mechanical stimulation can cause an increase in the discharge of nematocysts.
4. The increase in firing due to mechanical stimulation has an obvious benefit for the sea anemone. If a small food item (fish, etc) bumps into the anemone, it triggers nematocyst firing that can ensnare and/or impale and/or poison the prey.
5. Firing in response to chemical stimulation may be of survival value if either prey or predator of the sea anemone exudes the chemicals that cause the nematocysts to fire.
6. Since the nematocysts fire even after the rest of the cellular organization is disrupted, it appears that nematocyst discharge is not under nervous control. As mentioned above, nematocysts are "independent effectors".
7. Since the pH of the solutions is different, it may be possible that nematocyst firing is triggered by certain pH solutions. These crude activities do not really allow us to make this statement with much confidence since the presence of other ions or compounds might be the triggering factor. The importance of these observations is that they provide a direction for further investigation. Interested students might want to experiment with food extracts, egg white, blood etc. by poking acontia with a glass rod immersed in one of the solutions. Alternatively, they may wish to concoct test solutions using calcium or magnesium salts. They may wish to examine the effect of copper, poisons, other metals, drugs, alcohol or aspirin; can pH, or temperature changes cause a change in discharge? There are many opportunities for further investigation by your students.

8. Nematocysts play several roles in the life of members of the phylum Coelenterata. They are primarily concerned with defense or food getting behaviors and perform these functions by ensnaring, harpooning or poisoning the attacker or the prey.

KEY WORDS

acontia

cnidoblast

coelenterate

gastrovascular cavity

mechanical stimulation

micron

nematocyst

pH

sea anemone

sessile

substrate

Nematocyst Firing



Great numbers of nematocysts are present in a single sea anemone. Cnidoblasts are especially numerous in acontia, threadlike structures hanging inside the gastrovascular ("stomach") cavity of most sea anemone. In this activity you will have an opportunity to examine nematocyst firing.

Materials:

sea anemone
compound microscope
slide
depression slide
10% acetic acid
methylene blue dye (optional)
cover slip
pin or dissecting needle
eye dropper
ketchup
clam juice

Procedure:

1. Obtain an acontium from a sea anemone. If the sea anemone has been recently removed from its substrate (the surface to which it was attached), you will find numerous acontia streaming from the animal. Otherwise, you can cause the sea anemone to eject acontia by gently squeezing it or poking it on the side with a pin or dissecting needle.

2. Mount the acontia in a drop of sea water on a depression slide. Cover with a cover slip and observe.
3. Place a drop of 10% acetic acid (with or without a pinch of methylene blue dye) along the side of the cover slip and watch for nematocyst firing.

What is the effect of the acetic acid on the nematocyst firing?

What causes nematocyst firing in sea anemone? Perhaps we can see.

4. Obtain a fresh acontia and place it in a drop of sea water on a slide. Do not cover with a cover slip.
5. Using a pin or dissecting needle mechanically stimulate the acontia as you watch through the low power lens of your microscope.

Does mechanical stimulation seem to have an effect on the nematocyst firing? If so, what is the effect?

6. Repeat the procedure outlined in number 4 above. Introduce small amounts of clam juice. (Apply no mechanical stimulation) as you observe through the low power lens of your microscope. Do the nematocysts discharge?

7. Repeat the procedure outlined in number 6 above only substitute ketchup for the clam juice.

Do the nematocysts discharge?

BIOLOGICAL FACTORS:

Shellfish - Phylum Mollusca

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TEACHER BACKGROUND - The Ol' Shell Game

The phylum Mollusca contains the clams, snails and octopods. The term "mollusca" comes from a Latin word meaning "soft". As the name implies, molluscs are soft-bodied animals. They are bilaterally symmetrical with well-developed digestive, circulatory, respiratory and excretory systems. Many molluscs possess a calcareous shell. Most molluscs are slow-moving, creeping forms. Notable exceptions are the swift cephalopods (octopus, squids, chambered nautilus, etc.): There is great variety in both form and function within the molluscs.

The molluscan body plan involves three main body regions: the head-foot, the visceral mass and the mantle. The head-foot region is the locomotory and sensory portion of the body, upon which rides the visceral mass containing the excretory, circulatory, and digestive organs. The mantle, which secretes the shell, forms a fleshy cover over the visceral mass and a skirt around the foot. The gills are found in the mantle.

For many students molluscs are the most familiar group of marine animals. You can use this familiarity to your advantage. Encourage your students to bring in their shell collections. Display these shells and pictures of the living molluscs that once inhabited them. Supplement the following material with appropriate audio-visual aids.

Duplicate the text pages, one set is recommended per student. "The Ol' Shell Game" serves as background for the phylum Mollusca and the several activities which follow. You may elect to have your students complete the reading and text questions as homework. Follow up the assignment with a discussion of the material during which you provide answers to the questions in the text.

KEY - text questions

1. The answers will vary depending upon the background experience of your students. Since the question is phrased "which .. do you think?", any answer must be considered correct. This question is designed to make your students anticipate what is to follow

and to look for a specific piece of information within the text. To answer the inevitable student inquiries, the class Gastropoda contains the greatest number of species.

2. An important observation used by taxonomists to place animals in the phylum Mollusca is the presence of a trochophore stage during larval development.
3. The mantle covers the visceral hump, secretes the shell, and forms the mantle cavity which contains the gills.
4. a. the incoming water carries oxygen and food which are of importance to the mollusc.
b. The outflowing water carries away carbon dioxide and other wastes, the disposal of which is important to the mollusc.
5. The mere presence or absence of chitons in suitable area might give us information about environmental pollution. We might also use chitons as pollution indicators by placing chitons into areas of suspected pollution and watching their performance.
6. Since the scaphopods capture microscopic food organisms from the sand surrounding them by the use of threatlike tentacles, you would expect to find more scaphopods in sand than in mud. The organism can obtain food more readily in the sand. Tentacle operation is more difficult in mud.
7. Shells play many important roles: the most obvious is protection from predators. They also function in camouflage, in protection from drying, in attachment for body parts and muscles, in food getting, in protection from wave pounding, etc.
8. Water flows into the mantle cavity through the incurrent siphon. The water flows through the gills within the mantle cavity and is then expelled through the excurrent siphon.
9. By allowing the head to be rapidly retracted into the mantle cavity, torsion has offered the gastropods increased protection from attack, and has, thus, increased the survival chances of the gastropods.

10. Structures and behaviors that make marine scientists think that cephalopods are the most highly developed molluscs include:
- a. the possession of a large, differentiated brain
 - b. presence of well-developed eyes
 - c. rapid locomotory abilities.
 - d. sucker-bearing tentacles
 - e. direct development of young
 - f. protection of the "nest" as development occurs
- Any three of the above will suffice.

KEY WORDS

Amphineura

bivalve

Cephalopoda

cilia

detritus

excurrent siphon

foot

Gastropoda

gills

incurrent siphon

invertebrate

mantle

mantle cavity

mariculture

Mollusca

mucus

Pelecypoda

plankton

predator

radula

Scaphopoda

scavenger

taxonomist

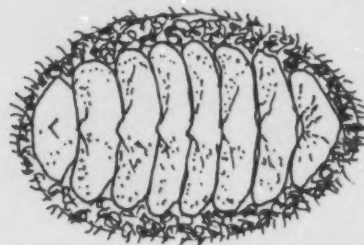
tentacle
torsion
trochophore
univalve
visceral hump
zooplankton

THE OL' SHELL GAME

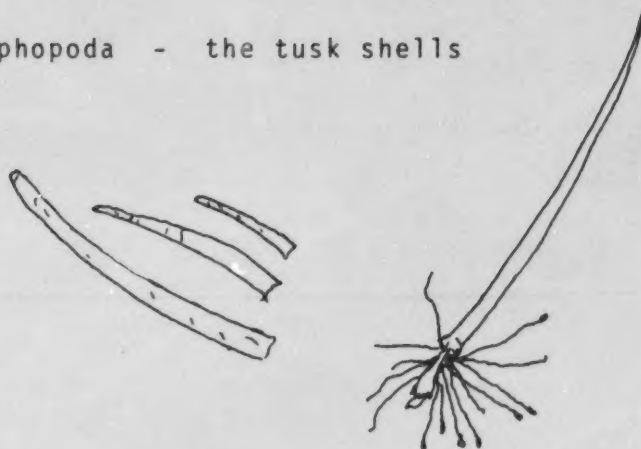
Sea shell collections have made the phylum Mollusca the most familiar group of animals in the sea. Collectors travel to all parts of the world to find new molluscs. For example, there was the 32 year old man who journeyed to a remote Indo-Pacific island to skin-dive and collect shells. Having picked up a uniquely decorated shell to examine, he was stung lightly on the thumb before he could drop it. He did not feel pain at first, but soon discovered difficulty in breathing and although the wound was little more than a puncture mark, he died within three hours. What is the fascination with this group of animals that would cause a man to travel half way around the world and eventually meet his death?

Over 80,000 living species of the phylum Mollusca have been described. Forty thousand of these are found in the sea making this phylum the most abundant marine animal group. There is great diversity within the phylum to which both clam and octopus belong. This large group is subdivided into five classes:

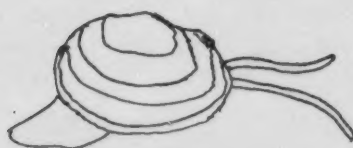
Amphineura - the chitons



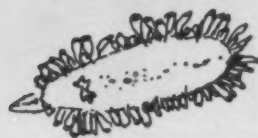
Scaphopoda - the tusk shells



Pelecypoda - the clams



Gastropoda - snails, slugs, nudibranchs, limpets, etc.



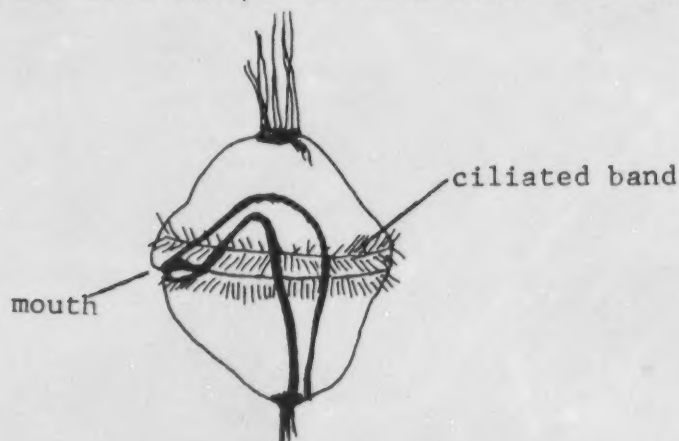
Cephalopoda - the octopuses and squids



1. Which one of the five classes mentioned above do you think has the greatest number of species?

Octopus, clams, snails, and squids certainly do not look very much alike. Why have biologists placed these different animals in the same group? In placing animals into groups, taxonomists look for similarities in development as well as for similarities in appearance.

Animals classified as molluscs go through a stage of larval development in which they look the same. The larval forms of marine molluscs, called trochophores, are drifting zooplankton. The trochophore larvae shown below is typical of marine molluscs. The hair-like cilia propel the larvae and also sweep food into their mouths.

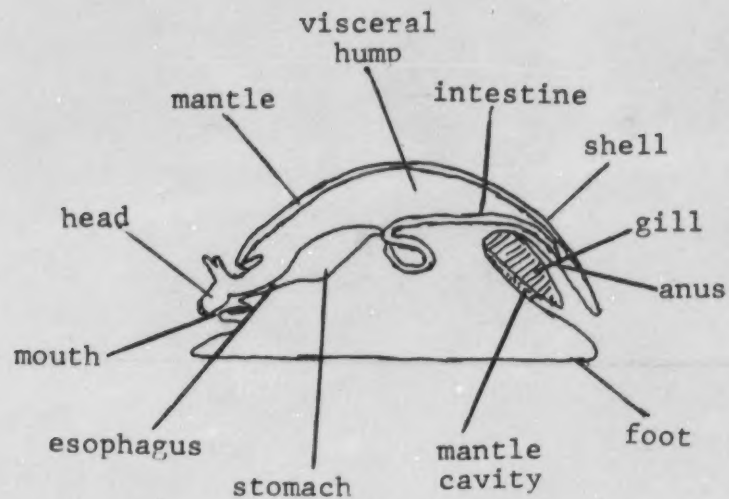


2. What is one observation taxonomists use to place animals in the phylum Mollusca?

The body of an adult mollusc has a head, a foot, and a visceral (VISS-uh-rul)hump. Inside the visceral hump are the digestive organs, excretory organs, and the heart. The visceral hump is covered by a mantle. The mantle is a thin skin that in most species secretes the calcium carbonate shell. The mantle hangs down over the sides and back of the body, forming a space called the mantle cavity. The gills are in this cavity. They are the respiratory organs of the aquatic molluscs. Undigested materials go from the anus into the mantle cavity before passing out of the animal.

3. What are two functions that the mantle performs?

In most molluscs, a current of water flows through the mantle cavity. The water carries in oxygen and food, and carries away carbon dioxide and other wastes. You might think that molluscs with a shell have a problem disposing of wastes. They do not. Water flows into the cavity through an opening called the incurrent siphon. The water circulates over the gills, where it picks up the carbon dioxide and wastes, and exits through the excurrent siphon.

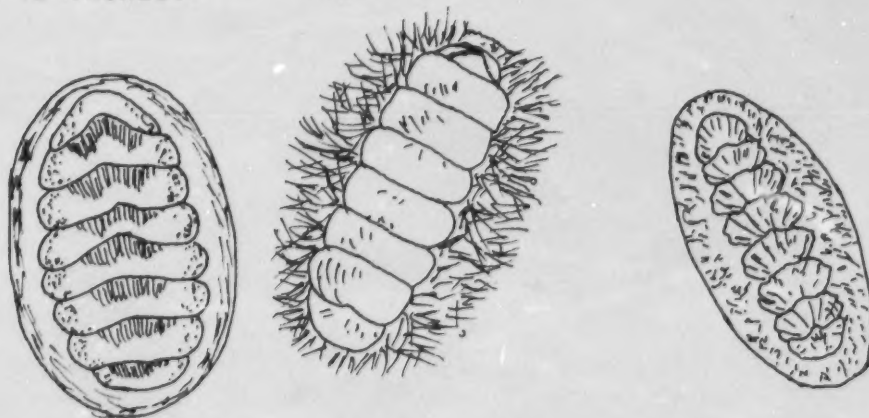


4. What substances of importance to the mollusc does the incoming water carry?

The type of shell or shells or the absence of shells and the type of muscular foot are also characteristics used to divide the molluscs into the classes mentioned.

Amphineura

The Class Amphineura includes chitons with a "shell" made up of eight partially overlapping plates lining the dorsal (back) surface of the body. The muscular foot of these molluscs is broad and well adapted for clinging to rocks. Most chitons are unable to keep their gills free of debris. The animals are therefore obligated to live in clear water such as is common to rocky shores. Food is obtained using a rasp-like radula to remove algae, detritus (dead and decaying material) etc. encrusted on rocks. Most species are light sensitive and are most frequently found under rocks or in tide pools. Adult chitons seldom reach a length longer than two inches. The Gumboot chiton, found on the West Coast of the United States, is the largest of all chitons and can grow to a length of 12 inches.



5. Since chitons can only live in clear water, how might we use them as an indicator of environmental pollution?

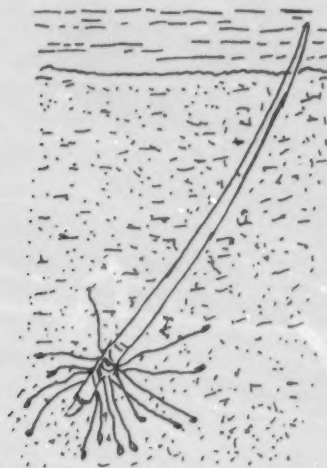
Scaphopoda

The class scaphopoda contains about 200 species of burrowing marine molluscs. These are the tooth or tusk shells. The shell is an elongated cylinder shaped much like an elephant's tusk. The attractive appearance of the shell and its relative scarcity are witnessed by the fact that Northwest coast Indians used these shells as money or wampum.



The shells, which are open at both ends, average 25 to 50 millimeters (1 to 2 inches) in length. The body is greatly elongated and the head and foot project from the larger opening of the shell. These animals burrow head down in sand or mud leaving only the posterior tip of the shell above the sand. Water is drawn in and expelled through the opening in the posterior tip of the shell. Oxygen and some food is drawn in with the water.

Using thread-like tentacles, scaphopods capture microscopic food organisms from the sand surrounding them.

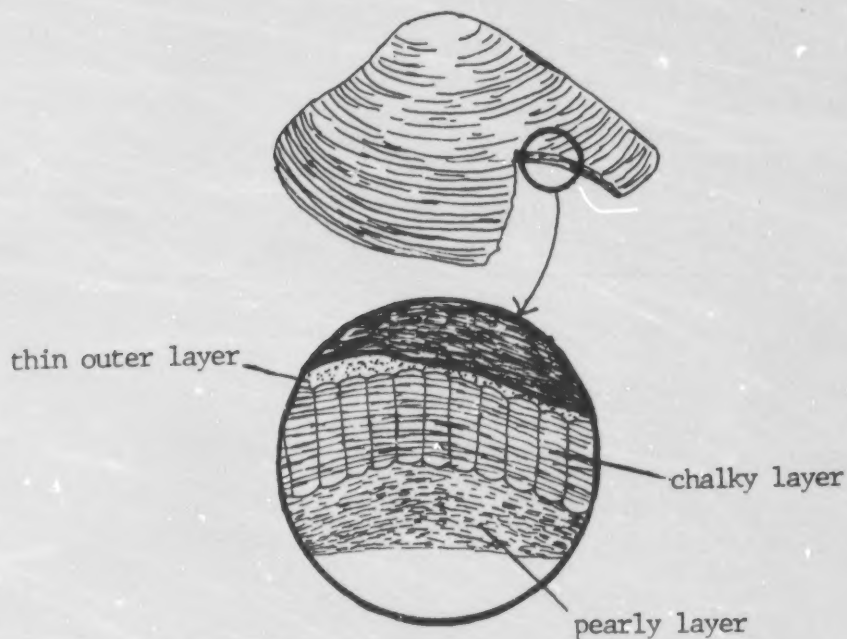


The majority of scaphopods live burrowed in sand under water ranging in depth from 6 to 1830 meters (about 20 to 5,500 feet). As a result the living animals are not frequently encountered. Judging from the number of shells washed up on beaches, however, scaphopods are not to be considered rare animals.

6. Considering the way that the scaphopods capture their food, do you think more scaphopod species would be found living in mud or in sand? Why?

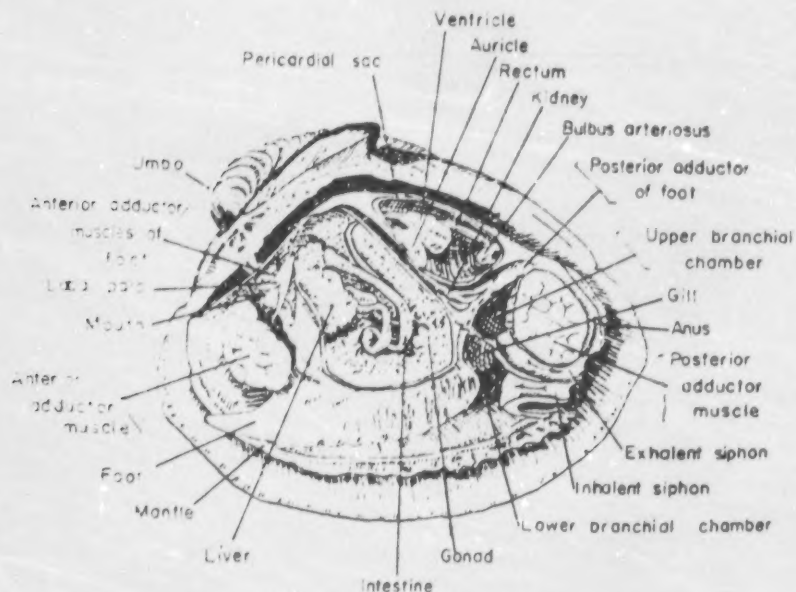
Pelecypoda

Molluscs like clams, oysters, scallops and mussels are called bivalves because their shells have two halves or valves. Bivalve molluscs belong to the class Pelecypoda. A hinge connects the two shells so they can be opened and closed by the animal. The shells are chalky structures made of calcium carbonate (lime) and other materials secreted by the mantle. There are three layers: an inner, pearly layer next to the mantle; a central chalky layer; and a thin outer layer (sometimes hard to identify) made of the same material as the hinge.



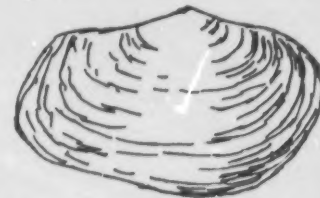
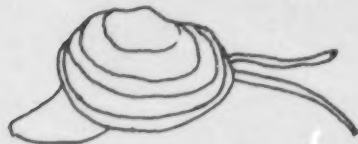
7. Shells play a number of different roles in the life of marine molluscs. What are two ways in which shells are used to help marine animals survive?

Pelecypoda means "hatchet footed". The hatchet shaped, muscular foot helps the molluscs quickly dig into mud or sand. Many members of this class spend most of their lives partly buried. The valves are kept slightly apart and two siphons are extended into the water. Water flows into the mantle cavity through the incurrent siphon. The water flows through the gills before it is expelled through the excurrent siphon. The gills remove dissolved oxygen from the water and release carbon dioxide. They also serve another important function. The gills are covered with a thin layer of mucus which traps small food particles. Cilia on the surface of the gills carry the food-bearing mucus to the mouth. These mucus-feeders feed on dead and decaying organic matter and the many microscopic plankton found in the siphoned water.



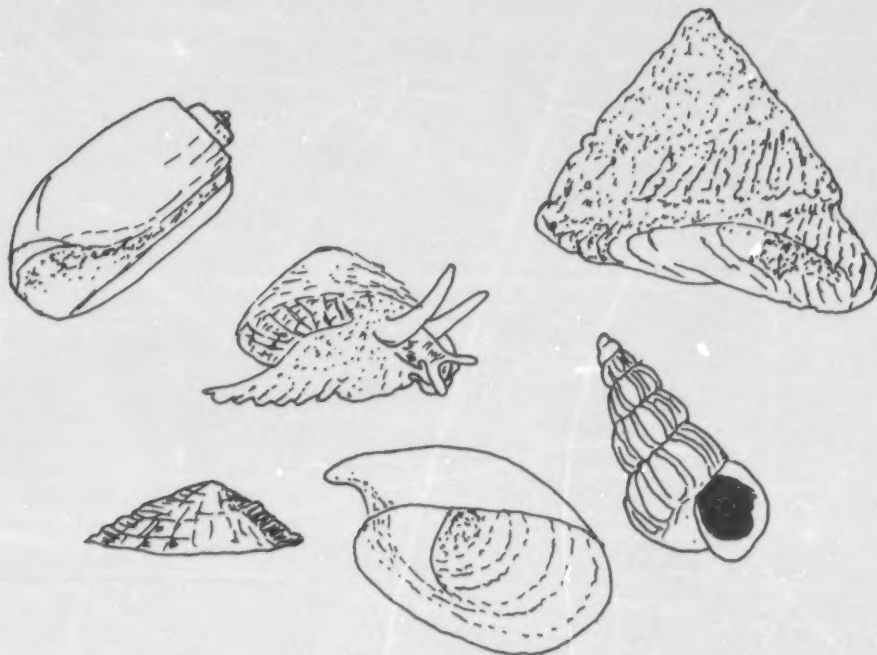
8. What is the path of water flowing through a pelecypod mollusc?

Many bivalve molluscs are important as food. Clams, oysters, scallops and mussels are all harvested in great numbers. Many of these species are cultivated by man and serve as the basis for thriving industries.

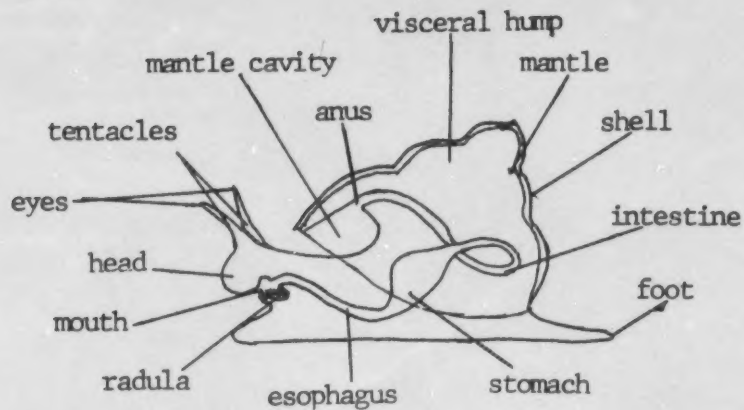


Gastropoda

The most successful group of marine molluscs is the gastropoda; snails, slugs, nudibranchs, limpets, and abalones. There are over 28,000 species of marine gastropods. Most of these animals have only one shell (univalves). Some have no shells.



All gastropods possess a flat, muscular foot used for creeping. Most gastropods are slow travelers with a top speed of about three meters an hour. Gastropods also have a head, usually with tentacles and eyes.

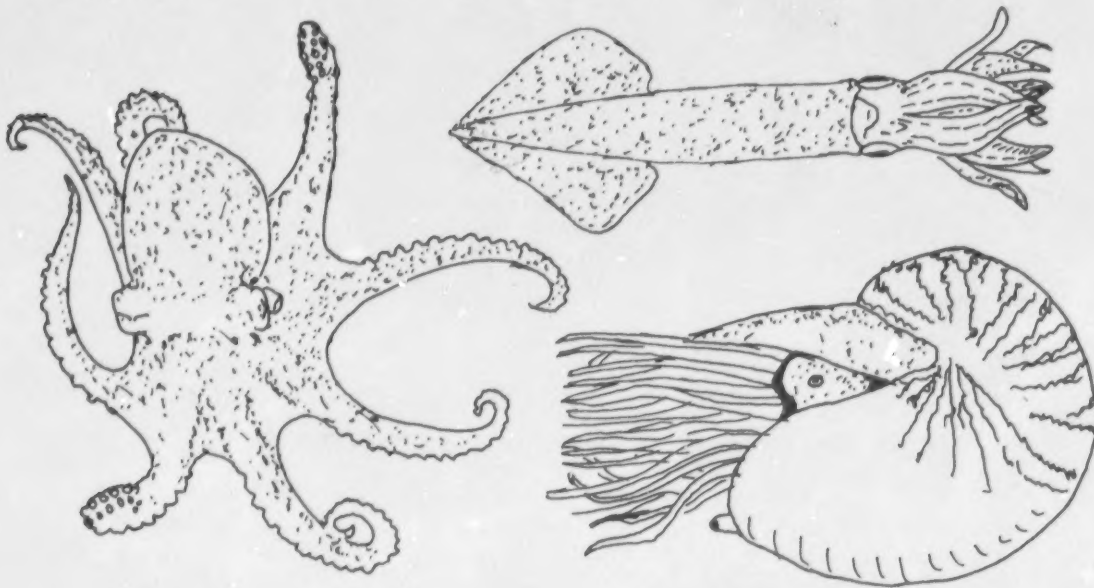


This group of molluscs possesses a rasping, tongue-like structure called the radula. The word "radula" comes from a Latin word meaning scraper. The ribbon-like oral structure contains rows of serrations or teeth which the gastropod uses to file its food apart. Sometime during the development of all gastropods torsion occurs. Torsion is a 180° rotation of the internal organs. This rotation results in the anus, the gills, and the mantle cavity (all originally at the rear) all being located immediately behind the head. The most widely accepted theory to explain the survival importance of torsion was advanced many years ago by the biologist Garstang. Garstang maintained that torsion allows the head to be rapidly retracted into the mantle cavity. This retraction of the head offers the gastropod protection from attack.

9. How has torsion increased the survival chances of gastropods?

Cephalopoda

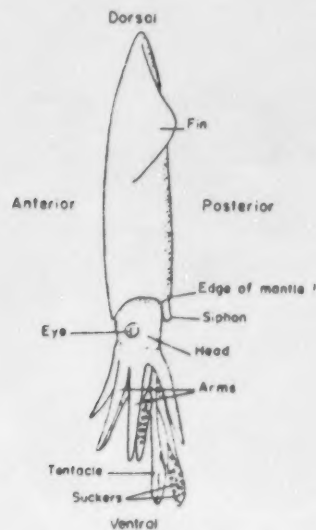
Octopus, squid, cuttlefish, and chambered nautilus belong to the Cephalopoda, or "head-footed" molluscs. Cephalopods are the most highly developed molluscs and may even be the most highly developed invertebrates.



The head of these "head-footed" molluscs is well developed and contains a large, differentiated brain. This complex nervous center allows the animals to be extremely active and provides for an effective control of the activity. Well developed eyes, similar to the human eye, are present. With the notable exception of the chambered nautilus, most cephalopods have no external shell. Instead, they have an internal pen which supports the body.

Cephalopods possess a siphon through which water can be expelled with great force. This stream of water propels the animal forward or backward in a jet-like manner. Some members of this group have fins which enable the animal also to swim in a fish-like fashion.

SQUID



The mouth is surrounded by eight or ten sucker-bearing tentacles used for gathering food and for reproduction. A strong, parrot-like beak, frequently covered with a poisonous slime, is present in the mouth for grasping food. Immediately behind the beak is a file-like radula which is used to grind through shells.

Effective protection is obtained via an ink sac. The cephalopod can discharge a cloud of black, inky fluid that hides its escape from enemies. The high degree of development of this group is also seen in its behavior, females frequently watch over the young, which develop directly (no larval stage), as they grow in a "nest".

The giant squid is probably the largest invertebrate in the world. It may grow to be eighteen meters long (about 58 feet) and weigh 1,800 kilograms (about 3,960 pounds). Sucker marks from these giants are often seen on the skin of deep diving whales. In spite of its reputation, the octopus is usually a timid animal. The largest octopus is found along the Pacific Coast. Its body can grow to a length of about 30 centimeters (about 12 inches). Its long slender arms, however, can give the octopus an overall length of five meters (about 18 feet)!

10. List three structures or behaviors that make marine scientists think that cephalopods are the most highly developed molluscs:

- a.
- b.
- c.

Molluscs play a variety of ecological roles in the life of the sea; from scavenger to predator. Their diversity, abundance and large range (where they are found) make the molluscs one of the most important groups of sea animals. Molluscs also play a large role in man's interactions with the sea. This group provides the "shell-fish" which are so widely harvested: clams, oysters, mussels, abalone, squid, octopus, etc. It also provides the most realistic hopes for "sea farming" or mariculture. The many members of the phylum Mollusca are both ecologically and economically important.

TEACHER BACKGROUND - Moving On

"Moving On" gives your students a chance to observe movement in a living marine gastropod. The procedure is straight forward and your students should have little trouble. You can readily obtain periwinkles (Littorina species) or similar single shelled gastropods from the intertidal zone or from biological supply houses.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished in pairs but may be performed well by groups of 3 or 4 if your supply of fingerbowls and gastropods is limited. The "Analysis and Interpretation" sections should be completed during the lab period since they rely on observations for answers. Note that there is a period of 10 to 20 minutes during which the stain acts. This time may be used for clean up or similar activities. Alcain blue stain may be replaced by any mucopolysaccharide stain. Caution your students that the stain will work equally well on their clothing and skin and that any and all spills should be promptly wiped up. Upon completion, provide time for a discussion of the procedure and results.

KEY

Analysis and Interpretation I

- A. Answers depend upon experimental results but normally the waves pass anterior-posteriorly from head to foot of foot.
- B. The wave movement propels the snail forward a minute step at a time. The wave of contraction push-pulls the gastropod along. This simple movement is really very elaborate and only now beginning to be fully understood. The slime trail has unique chemical properties that alternately act as a glue then as a lubricant depending upon the pressure placed on the slime by the gastropod. The stationary portion is held in place by the glue as the moving portion is easily moved over

the lubricated surface. Your students may have some additional creative ideas.

- C. The answers will vary depending upon experimental results. Differences in the waves help turn the animal (much like a caterpillar tractor).

Analysis and Interpretation II

A, B, & C answers depend upon experimental results.

- D. No, the slow rate of speed seems to indicate that the gastropod does not rely upon speed for protection. The most obvious means of protection is the shell.
- E. Answers to this may vary. You may wish to spend some time discussing the answers in terms of hypothesis formation. Current studies came from observations and questions just such as these. Some possible theories for the role of the mucus may include: glue, lubricant, and cushioning protection for the underside of the gastropod. Your students may have additional and perhaps more creative theories.

KEY WORDS

finger bowl
gastropod
locomotion
midline
molluscs
mucus
waves of contraction

MOVING ON



Most marine molluscs are not renowned for their blazing speed. Nevertheless, they have evolved effective and efficient means of locomotion. In this activity you will have an opportunity to observe some of the ways in which marine molluscs move.

Materials:

shelled gastropod (e.g. Littorina sps.)

finger bowl

glass (large enough to extend across finger bowl)

sea water

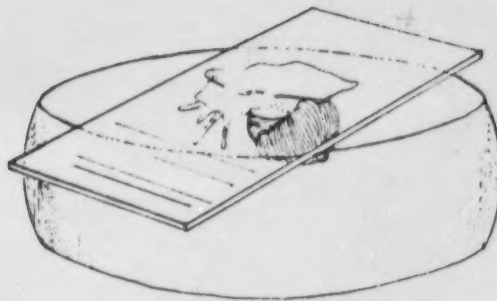
dissecting microscope

Alcain blue or similar stain

millimeter rule

Procedure:

1. Obtain a finger bowl and fill it with sea water.
2. Obtain a piece of glass long enough to extend across the finger bowl and wet it with sea water. Place a shelled gastropod upon the glass.
3. When the gastropod begins to crawl, invert the glass and place it over the finger bowl so that the snail becomes immersed in water.



Inverted Snail

Record the time _____

4. Observe the snail under the dissecting microscope.
5. In the space below sketch the muscular foot. On your drawing, label the foot and any cilia you may be able to see on the surface of the foot.

Analysis and Interpretation I:

- A. What is the direction of movement of the waves of contraction? (Toward or away from the head?)
- B. How might the direction of movement you observed help the gastropod move forward?
- C. Use your imagination to draw a line along the midline dividing the gastropod foot into left and right sides. Are the waves the same on the right as on the left?

If the waves are different, how does the difference affect the motion of the gastropod?

- 6. Record the time _____. Turn over the glass plate and remove the snail. Flood the surface with Alcain blue stain and allow the glass to stand for 10 to 20 minutes. (Caution: This stain will stain clothing and skin. Clean up all spills.) Gently rinse off the stain with cool tap water. The remaining track is a record of the gastropod's movement.

CLEAN UP your lab area as you wait for the stain to act!

Analysis and Interpretation II:

- A. How many millimeters did your gastropod move?
- B. Use the total distance your gastropod moved and the number of minutes during which you observed your gastropod to calculate the speed of the gastropod in:
1. millimeters per minute
 2. meters per hour (hint: there are 1000 millimeters in a meter and 60 minutes in an hour)
- C. Record your rate (in meters per hour) on the blackboard. Use the pooled results to calculate the class average. Record the average. How does your speed compare with the class average?
- D. Is it reasonable to assume that your gastropod relies heavily upon speed to escape from enemies?

How does your gastropod probably protect itself from enemies?

- E. The trail you observed on your glass is due to the presence of a mucus protein. You probably have seen similar trails where garden snails and slugs have eaten your favorite plants. What is the most likely role of the mucus in locomotion?
(Hint: the gastropod doesn't use the trail to find its way home).

USING SOAP AND WATER, CLEAN YOUR GLASS PLATE and then replace the rest of the materials you used.

TEACHER BACKGROUND -- Inside the Living Clam

Clam dissection is a fairly standard laboratory activity found in many high school and college courses. While there is much to be learned from such dissection, dissection of the clam tends to be frustrating for most students. The internal organs are difficult to locate, similar in color, and rather shapeless. "Inside the Living Clam" minimizes these frustrations by combining some internal anatomy with some observations of a functioning gill.

Duplicate the activity pages. One set is recommended per student. This activity is best performed by pairs. Special caution is needed in the opening of the clams. Be sure to alert your students to the potential danger and be alert to the way your students attempt to open the clams. Circulate through the room as your students perform the activity and provide the assistance required. Have your students place the clams in a container you provide for that purpose. You may use the clams for clam chowder (see the next activity) providing your students do not place the stained tissue in the container with the clams. Plan to allow time for a discussion of the activity and to provide answers for the questions found in the text.

KEY - text questions

1. a. The clam possesses two shells (valves).
b. Answers depend upon the experimental results.
c. The clam is probably younger than the estimate. Changes in the factors listed will increase the number of sets of rings making the clam appear older than it really is.
3. a. One obvious advantage is that the smooth inner surface reduces the likelihood of tissue damage when the soft inner tissues of the clam are moved across the hard shell lining. Your students may see other advantages.
4. a. The clam has two siphon openings, an incurrent siphon and an excurrent siphon.

- b. A simple experiment to show the path of water flow through a clam might involve placing dyed water in front of one siphon opening and observing the results. More elaborate schemes would yield more information. The above would only show water movement at the siphons. To learn how the water moves within the clam, dissection would be necessary.

Your students may have some creative ideas of their own.

5. The foot is a muscular organ used for locomotion and burrowing.
6. The answer depends upon the experimental observations.
7. The outer surface of the gill is covered with cilia.
8.
 - a. Carbon dioxide is being carried to the gills for disposal.
 - b. Oxygen is being picked up by the blood in the gills. This question provides an opportunity to talk about the mechanics of gas exchange in living organisms.
9. The labeled drawing should be similar to that included in the text.
10.
 - a. The cilia beat rhythmically to move water over the surface of the gill.
 - b. The path of water flow through the entire gill involves the flow of water (propelled by cilia) between gill filaments, through water pores into spaces called water tubes, then into the excurrent siphon. It is possible that only portions of this process may be seen. The drawing provided will help your students identify the path and the structures they observe.

Analysis and Interpretation

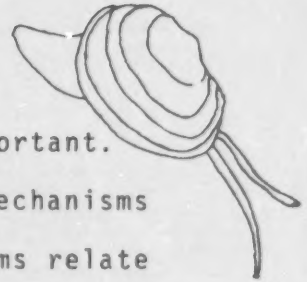
1. The ciliary movements pass the trapped particles of food from the gill surface into the mouth of the clam where they can be ingested.
2. The ciliary-mucoid method of feeding is more common among attached marine animals. "Why" is a teleological question that might best be answered by "Why not?" Here are some thoughts: The number of calories provided by this type of feeding might not be sufficient to support a free swimming organism which because of locomotion requires more calories than an attached organism; animals that move through the water column might find a filtering mechanism more useful. The real value in the "Why" question comes from the discussion that it can spur.
3. The answers will vary. While evaluating and discussing the proposed experiments, deal with the idea of "experimental control". Do the experiments suggested provide information that will measure the effect of temperature on the gill action?
4. The clam obtains its food from the water above the bottom by extending its siphon up out of the mud and drawing in water. This seemingly simple adaptation is actually critical to the survival of the clam. Clams can live in low oxygen containing muds and low food containing sands by feeding elsewhere. The clam can enjoy the protection of being in the bottom substrate while not facing the hardships faced by those organisms that must obtain their food and oxygen from the bottom muds.

KEY WORDS

afferent vessels
ciliary-mucoid feeders
concentric
efferent vessels
foot
gill
mantle
mucous

pelecypod
Pelecypoda
scalpel
siphon
tendon

INSIDE THE LIVING CLAM



Clams are economically and ecologically important. These bivalves have evolved highly developed mechanisms for survival in the sea. Many of the mechanisms relate to straining and sorting microscopic food material suspended in the water. The gills of the clam (class: Pelecypoda) serve a dual purpose: (1) to provide oxygen to the organism and (2) to move food particles toward the mouth. Pelecypods like the clam are called "ciliarmucoid feeders". This isn't a very helpful term unless we look at its make up. In the clam, the action of hair-like cilia ("ciliary") combines with adhesive mucus secretions ("mucoid") to catch microscopic food particles ("feeder") and pass them along to the mouth. To aid this process the clam circulates water (containing food particles) in through the incurrent siphon, over and under the gills, and out through the excurrent siphon. In the following activity you will have an opportunity to observe the body plan of the clam and to observe the functioning of pelecypod gill tissue.

Materials:

live clam
dissecting kit
microscope slide and coverslip
compound microscope
methylene blue stain
filter paper

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1. Obtain a living clam. Observe the external anatomy.

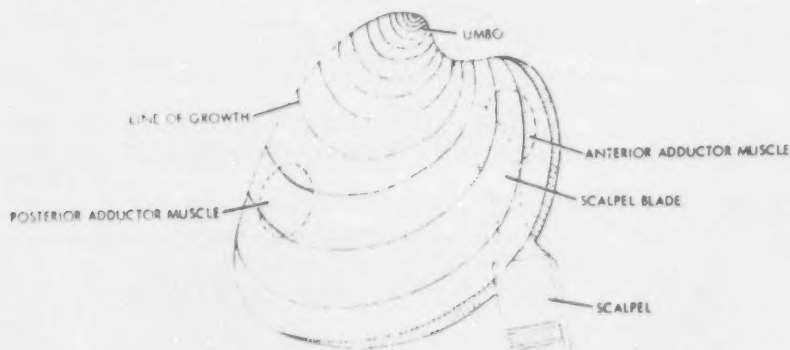
a. How many shells (valves) does the clam possess?

b. New shell is formed at the margin (edge) of the shell by the mantle. The concentric rings you see are a result of non-uniform growth. Much like tree growth rings, growth lines on the shell are more closely spaced during the winter than during the summer. According to this theory each set of close rings and wide rings represents a year's growth. Estimate the age of the clam you are studying:

c. Changes in clam rings can also be produced by sudden changes in temperature, lack of food, disease or other stress. Considering these possibilities, is your clam probably older or younger than your estimate of age? _____

Explain your reasoning. _____

2. Carefully open the clam. You may open the clam by inserting a scalpel blade between the two shells (CAUTION: THE BLADE IS VERY SHARP and the shells are tightly held together). Patience will be rewarded since the clam will get tired and you will be able to insert the blade further and to cut the muscles holding the shells together. (Hint: Careful cutting of the tendons holding the hinge together can sometimes make it easier to insert your scalpel). The diagram below shows the technique.



3. Remove the mantle layer from a part of one valve. Note the smooth, fine-grained inner surface of the valve. The shell lining is called mother-of-pearl.

a. What is an advantage to having this smooth inner surface?

4. Find the siphons which extend out from one side of the clam's body. These structures regulate water flow through the clam.

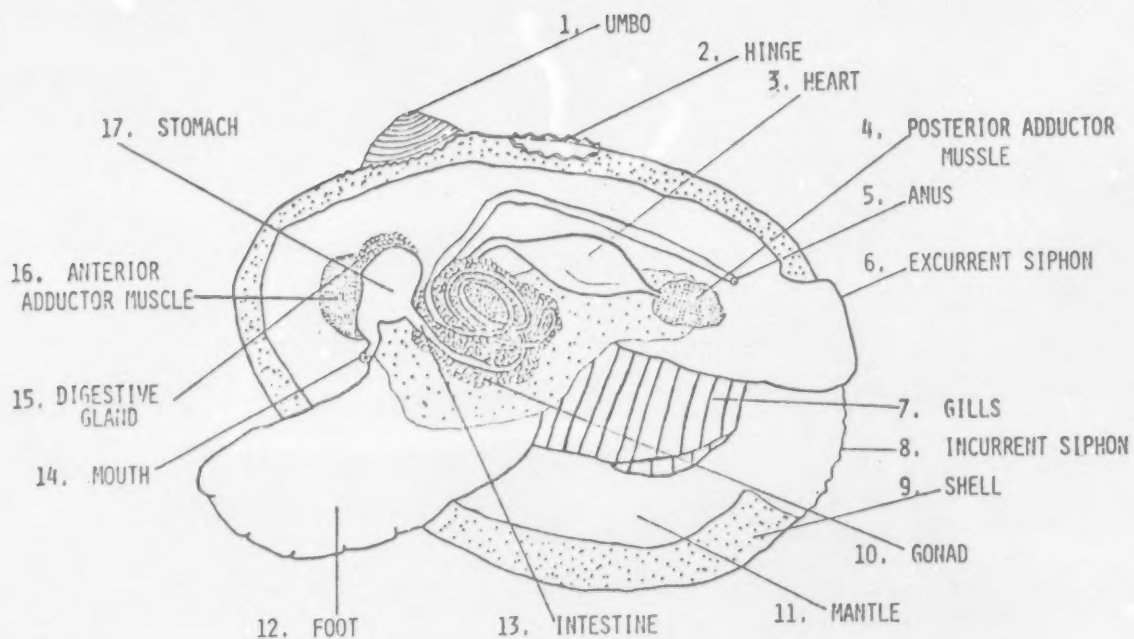
a. How many siphon openings does your clam have? _____

b. Design an experiment that would help you trace the path of water flow through the clam.

5. Locate the large muscular structure which makes up a large part of the body. This tissue mass is known as the foot. What is the role of the foot in the life of the clam?

6. Use the following drawing to locate the gills that lie on either side of the foot in the mantle cavity. You may need to remove part of the mantle to reveal the gill containing cavity below.

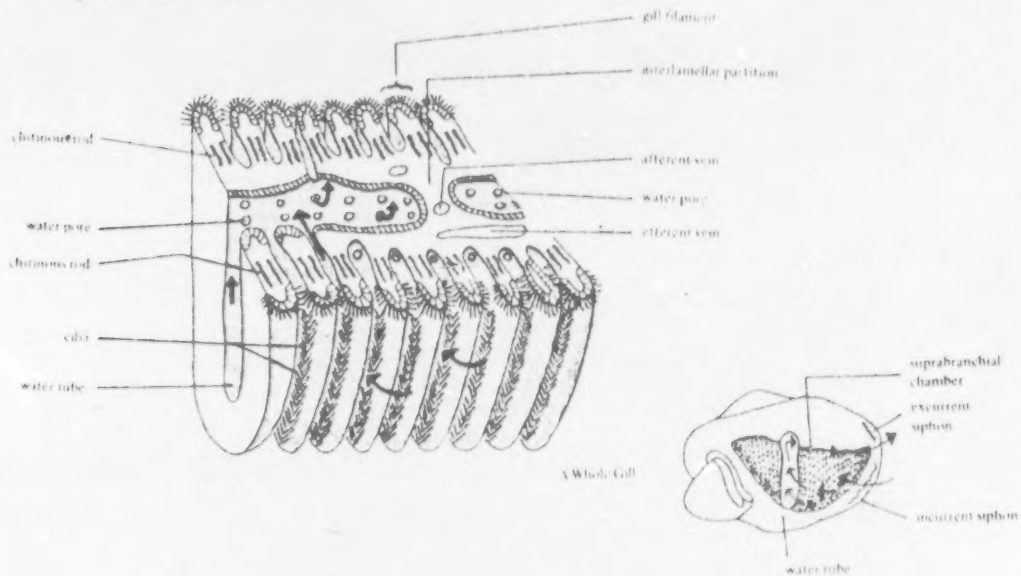
CLAM ANATOMY



How long are the gills? _____ mm.

7. Use your scissors or a scalpel to cut a 4mm x 4mm piece of gill tissue. Place the tissue on a clean microscope slide, add a drop of clean salt water and a coverslip. Observe the gill tissue under low and high powers. What structures cover the outside of the gill?

8. Use the drawing below to help you identify the structures you observe.



Both afferent vessels (to the gills) and efferent vessels (from the gills) pass close to the gill surface.

- a. What substance is being carried to the gills for disposal?
- _____
- b. What substance is the blood picking up in the gills?
- _____

9. In the space below, sketch a small portion of the gill tissue containing cilia. Label the structures in your drawing.
10. Add a drop of methylene blue dye to the edge of the coverslip. By placing a small piece of filter paper at the opposite edge of the coverslip, you can "pull" the drop of stain under the coverslip. Observe ciliary movement and the direction of water flow by following the movement of the blue dye.
- a. How do the cilia accomplish water movement?
- _____
- _____
- b. What is the path of water flow through the gills?
- _____
- _____
11. Return your clam to the container provided by your teacher.

Analysis and Interpretation

1. The gills of the clam serve a food gathering function as well as a gas exchange function. The gills produce a mucous covering which traps small particles of food. How might the ciliary movements aid the clam in feeding?
2. In which group of animals, free-swimming marine animals or attached marine animals, would you expect to find the "ciliary-mucoid" method of feeding more common? Why?
3. Marvin Marine, scientist, noticed that the clams in his aquarium would open when the temperature was 15°C. Above this temperature, the clams remained closed. Marvin wants to measure the effect of temperature on the gill action of the clam. Design an experiment (and describe it below) which would measure the effect of temperature on gill action. In your description include the following:

Purpose:

Materials:

Procedure:

4. While the clam lives in the sand or mud, it obtains its food from the water above the bottom. How does the clam achieve this goal?

TEACHER BACKGROUND - Home Economics

Not the least interesting thing about clams is their taste. The following recipes are included so that you might share this taste experience with your students. It is possible to prepare the items as a demonstration or to bring the prepared food from home for sharing. The most instructive approach involves student participation.

If you elect to have the students prepare the food, there are some things to keep in mind. Before beginning, read and understand the sequence of steps. Anticipate any problems your particular class might have. Be continually aware of hot items and knives. All of the ingredients may be purchased in most grocery stores. Provide cups and spoons for serving. Serve a small amount to each student, but force no one to eat. Your enthusiastic consumption will do more than requiring them to eat the prepared food.

Most of these items may be prepared in the classroom. All may be prepared on an electric hot plate or conventional stove if you have access to one (cafeteria staff are sometimes quite willing to allow some of their equipment to be used in the afternoon).

Use of canned clams is, of course, possible. If you use fresh clams, it may be wise to pre-cook them and remove and discard soft parts from horse clams after cooking. Bring the pre-cooked clams to class for the students to chop. For clam cooking see (Steamed Clams with Broth".

This is a good opportunity to expand measurement skills. The recipes can be readily metricized. This activity also provides a good exercise in following directions. HAVE FUN!

The first recipe has been presented in a format that you might wish to use if you elect to have the students do the cooking.

KEY WORDS

chowder

dash

dice

ingredients

utensils

DOWN HOME NEW ENGLAND CLAM CHOWDER

A tasty white chowder made from your friend the clam.

Ingredients:

12 medium size butter or steamer clams chopped

or

4 medium horse clams chopped

3 diced bacon strips

$\frac{1}{2}$ cup chopped onion

2 $\frac{1}{2}$ cups diced potatoes (dice: to cut into small cubes)

1 $\frac{1}{2}$ cups hot water

1 teaspoon salt

Dash pepper

2 cups milk

1 tablespoon butter

parsley sprigs

Directions:

1. Place the bacon in the soup pot and cook the pieces until crisp.
2. Add the onion to the soup pot. Cook until the onion is tender. The onion will become nearly transparent when it is cooked.
3. Add potatoes, water, salt, pepper and clams.
4. Cover and cook slowly over medium heat for 15 to 20 minutes until potatoes are tender.
5. Blend in milk and butter.
6. Cook until heated.
7. Place in cups and put a small parsley sprig on each cup.
8. Serve and enjoy your homemade chowder!

Makes 12 half cup servings

STEAMED CLAMS WITH BROTH

Ingredients:

4 quarts fresh clams (*If freshly dug, allow the clams to "spit"*
 2 cups cold water *in a bucket of clean salt water for several*
 butter *hours to get rid of sand. $\frac{1}{2}$ cup corn meal*
 lemon juice *may be added to encourage "spitting".)*
 salt
 pepper

Directions:

For six generous servings, use four quarts of fresh clams. Scrub thoroughly in running water to remove sand. Put clams in upper section of a steamer, over two cups cold water in lower section and cover. Cook over low moderate heat steaming until shells open. Serve with individual dishes of melted butter seasoned with lemon juice, salt and pepper. Remove from shells, dip into the melted butter and eat all but the neck or siphon. Allow liquid to settle and serve broth either hot or cold with crisp crackers.

CLAM BISQUE

Ingredients:

$7\frac{1}{2}$ to 8 oz. fresh clams (including liquid)
 1 cup water
 1 to 2 teaspoons salt
 2 teaspoons grated onion
 2 teaspoons finely minced parsley
 2 cups milk
 2 tablespoons butter, melted
 1 tablespoon flour

Directions:

Mix together and simmer 3 minutes the liquid drained from $7\frac{1}{2}$ to 8 oz. fresh clams (minced), 1 cup water, 1 to 2 teaspoons salt, 2 teaspoons grated onion, 2 teaspoons finely minced parsley.

Add: 2 cups milk

Stir in a paste (roux) made of 2 tablespoons butter, melted and 1 tablespoon flour.

Boil one minute stirring continuously, then place over boiling water until time to serve. Before serving stir in the minced clams. Serve garnished with minced parsley.

FRITTERS

Ingredients:

Geoduck necks (cut into individual pieces)

Directions:

Heat fat in deep kettle until a cube of bread browns in 50 seconds (375°). Cut geoduck neck into individual pieces then dip geoduck clam in fritter batter (see below) and immerse in hot fat. Fry quickly until golden brown (3 to 6 minutes). Drain on absorbent paper. Serve with lemon and tartar sauce.

FRITTER BATTER

Ingredients:

2 eggs (slightly beaten)
½ cup milk
1 cup flour
1 tablespoon baking powder
1 tablespoon salt
1 tablespoon melted fat or cooking oil

Directions:

2 eggs, slightly beaten. Stir in ½ cup of milk. Sift together and beat in 1 cup flour, 1 tablespoon baking powder, and 1 tablespoon salt. Beat in 1 tablespoon melted fat or cooking oil.

WHITE CLAM SPAGHETTI SAUCE

Ingredients:

4 tablespoons olive oil
 4 tablespoons butter
 2 cloves garlic
 3 tablespoons chopped shallots
 2 cups ground or minced clams (butter, razor or geoduck)
 1 cup clam juice
 1/4 cup chopped parsley
 1/2 cup parmesan cheese
 1/2 pound linguini spaghetti

Directions:

Melt butter and oil in frying pan, add undrained ground or minced clams to mixture after sauteing garlic and shallots in butter mixture. Do not substitute onions for shallots. Add clam juice and simmer gently for 20 minutes. Meanwhile cook spaghetti in boiling salted water until done. Drain. Arrange on heated platter. Pour clams over spaghetti. Sprinkle with parsley and parmesan cheese. Serve hot. Makes six servings.

STUFFED BUTTER CLAMS

Ingredients:

1 dozen butter clams (3/4" size)
 1 medium onion
 2 1/2 cups Ritz or soda crackers, about 6 oz.
 1 medium green pepper, chopped fine
 salt and pepper to taste
 dash of Worcestershire sauce
 butter

Open raw clams, save nectar and shells. Grind alternately clams, crackers, and onion. Add green pepper to mixture. Moisten with nectar until mixture is quite moist. Place mixture in shells and dot with butter. Bake about 20 minutes at 325° until bubbly and golden brown. Makes 24 appetizers or may be used as entree for 4 or 6 persons. Mixture may be made ahead of time and refrigerated. This recipe may be used for razor clams.

TEACHER BACKGROUND - Shellfish and the Red Tide

The threat of poisoning from a "red tide" is enough to halt the most avid oyster eater in mid bite. The article which is reprinted here gives your students an introduction to shellfish and the red tide. The student activity involves identifying main ideas and their supporting details. Main idea identification is a primary reading skill and one that is critical to the reading of the fact-filled literature of science. Unlike some authors who seem to delight in hiding the main idea, Norris et al. have chosen to emphasize the main ideas in bold type. This activity, while giving your students factual information on red tides, provides practice in sorting subordinate ideas from main ideas.

Duplicate the activity pages. One set is recommended per student. This activity is best completed by individuals working alone either as homework or as a classroom assignment. Before you discuss the article with your class and provide answers for the activity questions, you may elect to have your students meet briefly in small groups to discuss and share their findings. As always, use the approach that works best with your class.

KEY

MAIN IDEAS 1 - 6 are found in bold type in the text. The supporting details will vary somewhat but should all come from the paragraph(s) following the bold type. During the discussion, it is sometimes helpful to list the supporting details and construct a simple hierarchy which shows their relative importance.

- A. It is likely the authors emphasized the main ideas to facilitate understanding and to aid people in finding the information they desire as they skim the article. This question may be used as a springboard for a discussion of the other manners in which authors help the reader to comprehend the material (graphics, glossary, etc.)

KEY WORDS

bold type

detail

main idea

paragraph

red tide

shell fish

WASHINGTON SEA GRANT PROGRAM



WSG-AS 73-2
SHELLFISH AND THE RED TIDE

By Louisa Norris, Kenneth K. Chew, and Alyn C. Duxbury

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SHELLFISH AND THE RED TIDE

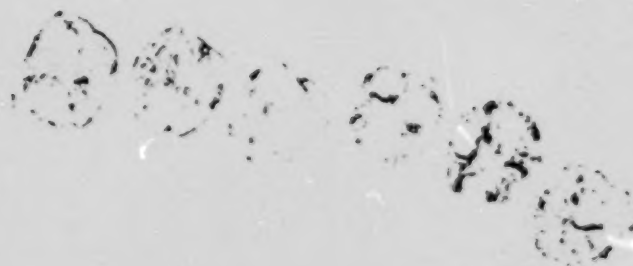
LOUISA NORRIS, KENNETH K. CHEW AND ALYN C. DUXBURY

This tomato soup-colored red tide was caused by a non-toxic dinoflagellate, *Noctiluca*. Red tide was washed onto shore at Clam Bay near the town of Manchester in Puget Sound during June, 1972. Others can be expected this month. Before the water clears the stench is terrible.

Photo by James G. Eagleton



Blooms of tiny floating organisms can color the sea surface red. Some of these organisms, when consumed by shellfish, are harmless; others can render shellfish deadly poisonous. Both types appear in Northwest waters.



The toxin-producing dinoflagellate, *Gonyaulax catenella*, can be part of the diet of filter-feeding shellfish. When the toxic *Gonyaulax* becomes dense enough, the shellfish may accumulate enough toxin to be harmful, even deadly, to man while showing no effects of the toxin themselves. Shellfish can become toxic when *Gonyaulax* is not dense enough to form a visible red tide.

During periods of rapid growth "blooms," *Gonyaulax catenella* forms chains of cells. The chains are usually two to eight cells in length but are sometimes as much as 32 cells long. Each cell is an individual organism capable of living independently. Cell diameter averages about 1/500 inch.

Photomicrographs by Louisa Norris. She and Kenneth Chew are the only research team who is culturing this toxin producing *Gonyaulax* and keeping it reproducing in their UW laboratory. They supply scientists all over the world.

What is a red tide?

Sometimes during late spring, late summer, or fall, color appears in the water — in localized patches or streamers. These appear suddenly, last a few days, and mysteriously disappear.

In Washington waters, one sees this color issuing from channels that connect small bays with Puget Sound or the Strait of Juan de Fuca. The discolored areas are usually some shade of red and are commonly referred to as red tides. Often the red tides in central Puget Sound, for example, look like cream of tomato soup. Close inspection shows that this color stems from very small individual particles, visible to the unaided eye. They may even feel gritty when rubbed between the fingers. Each of these particles is an individual organism known as *Noctiluca* — a member of the dinoflagellates, which are one-celled and have both plant and animal characteristics. *Noctiluca* (meaning night light) is not toxic and usually gives rise to brilliant displays of bioluminescence at night when the water is disturbed.

No one knows precisely what causes this red tide to form. We do know that a "seed" population of *Noctiluca* normally exists in the plankton and that under certain water and weather conditions *Noctiluca* will have a spurt of growth, dividing to form millions and millions of single-celled individuals. This rapid development of a dense population is often called a bloom. These cells can be further concentrated by onshore winds, which blow surface waters containing *Noctiluca* against a shoreline or by converging currents, which carry the cells to where the currents meet and form a concentrated band of *Noctiluca* color.

Several kinds of red tides in Washington waters are caused by a variety of dinoflagellates and other one-celled creatures in the plankton. The red tide of *Noctiluca* is just one kind. Other red tides are similar to *Noctiluca* tides in their patchy distribution, temporary nature, seasonal occurrence from spring into fall, and mode of formation, but *Noctiluca* forms our only tomato soup tide. Other "red" tides vary in color from pink to brick red to amber or rust, depending on which plankton organism is forming the tide.

What is the relation between red tides and poisonous shellfish?

News of a red tide strikes alarm among people who enjoy clams, mussels, and oysters because folklore and medical records tell us that red tides can cause these molluscan shellfish to be poisonous. In fact, only some of the red tides cause toxic shellfish while other red tides leave no harmful effects in the shellfish. Only one of the Washington red tide organisms, *Gonyaulax catenella*, is known to produce a toxin. This species has been the cause of outbreaks of shellfish toxicity from Alaska to California. *Gonyaulax* is microscopic in size and forms red tides that vary from amber to red-rust in color.

Filter-feeding shellfish, such as clams, mussels, and oysters, gather their food supply by filtering the plankton organisms out of the surrounding water at a remarkably high rate. For example, a large oyster can pump and filter as much as 20 to 30 quarts of water an hour. Thus, it is easy to see that shellfish can consume enormous numbers of the tiny organisms that make up a red tide, and if the red tide is caused by the toxic *Gonyaulax*, the shellfish can quickly become poisonous.

The presence of a red tide could be a warning that the shellfish may be poisonous, but the absence of a red tide does not mean shellfish are safe to eat. One reason is that, because of their enormous filtering capacity, shellfish can strain out enough *Gonyaulax* to become toxic even when a *Gonyaulax* bloom has not become dense enough to be visible as a red tide. Secondly, some shellfish tend to retain the toxin for varying periods of time, weeks to months depending on the kind of shellfish and the water temperature. Thus, they may be toxic long after a bloom or a visible red tide has gone. In fact, butter clams in some Alaska beaches are toxic year around.

For some reason not yet completely understood, the shellfish themselves are very seldom harmed by the toxin they have acquired,

but other animals, including man, can be poisoned if they eat enough toxic shellfish. The toxin is an extremely powerful nerve poison which can cause temporary paralysis and even death if enough toxin has been consumed to paralyze the breathing mechanism.

What protection does the public have against paralytic shellfish poisoning?

It is not possible for the shellfish-eating public to distinguish between toxic and non-toxic shellfish or to destroy the toxin by normal methods of cooking shellfish. Therefore, the Washington State Department of Health (now the Health Services Division) and the Washington State Department of Fisheries have been co-operating for many years in an effort to reduce the potential risk to the public of paralytic shellfish poisoning by (1) regulation of sport fishing for shellfish in areas likely to have toxic shellfish and (2) a surveillance program for commercial areas and certain other sport shellfish areas. This program includes semi-monthly tests of shellfish by the Health Services Division and local health departments to determine whether they contain toxin. If the toxin content of the tested shellfish exceeds levels considered safe by federal standards, harvesting areas are closed to protect the consumer. Since this program was instituted there has been no known case of paralytic shellfish poisoning from shellfish commercially harvested in Washington.

The sport fishing regulations, which are published annually and are available in sporting good stores, state that open seasons and areas for mussels and clams, other than razor clams, are:

Open year around in Willapa Harbor, Grays Harbor, and Puget Sound east of Dungeness Spit. Open November 1 through March 31 on Pacific Ocean beaches and Strait of Juan de Fuca west of Dungeness Spit.

These latter beaches with restricted open seasons have had sufficient outbreaks of shellfish toxicity in the past to warrant closure at certain seasons and are open only during the months when outbreaks are unlikely to occur. Occasionally areas which are normally open require closure and are posted. Razor clams are excluded from the regulation because the toxin is concentrated in the digestive gland, which is never eaten.

What precautions should the public take in gathering shellfish?

1. Gather clams, mussels and oysters only in areas known to be open. If in doubt, contact local health authorities — county health officer or sanitarian. Boaters going north should note that British Columbia waters have also had frequent outbreaks of paralytic shellfish poisoning and that complete surveillance is impossible on that extended coastline. There is no automatic closure of potentially hazardous beaches in British Columbia. Local inquiries should be made about whether shellfish are safe to eat.

2. Forget the old saying that shellfish should be eaten only during months with R in them. Many people think the saying means that shellfish are always safe to eat during the R months, but as the closure dates indicate, there have been outbreaks of shellfish toxicity in certain Washington beaches in the R months of April, September, and October. That saying originated in Europe and was based on factors connected with the reproductive events of oysters, not with paralytic shellfish poisoning. The oysters in Europe brood their young and are unpleasant to eat from May to August because of the crunchiness of the baby oyster shells in the brood chamber. In addition, the spawned-out oysters of this period are generally less plump and tasty.

MRS. NORRIS and DR. CHEW are in the College of Fisheries; and DR. DUXBURY is with the Sea Grant Advisory Service of the Division of Marine Resources at the University of Washington.

SHELLFISH AND THE RED TIDE



Finding the main idea in a paragraph is an important step towards getting information from your reading. The main idea in a paragraph contains the thought that links all the facts together. Main ideas can be found in different parts of a paragraph. In the article "Shellfish and the Red Tide", the main ideas are given in bold type (darker print).

Main ideas are supported by important details. The details may be examples or facts. As you read the article, fill in the main idea and the important details in the diagrams below.

MAIN IDEA 1: _____
Detail 1: _____
Detail 2: _____
Detail 3: _____

MAIN IDEA 2: _____
Detail 1: _____
Detail 2: _____

MAIN IDEA 3: _____
Detail 1: _____
Detail 2: _____

MAIN IDEA 4: _____
Detail 1: _____
Detail 2: _____
Detail 3: _____

MAIN IDEA 5: _____

Detail 1: _____

MAIN IDEA 6: _____

Detail 1: _____

Detail 2: _____

- A. Why might the authors emphasize the main ideas by placing them in bold type?

BIOLOGICAL FACTORS:

The Crustaceans - Phylum Arthropoda

396

TEACHER BACKGROUND - Arthropods: They're Everywhere! They're Everywhere!

The Phylum Arthropoda contains more species of animals than all other phyla combined. The fact that almost all marine representatives of this phylum come from the Class Crustacea is somewhat of a help to the marine taxonomist. However, the 25,000 or so known crustaceans still present a formidable learning task. In the following brief introduction to the arthropods representative samples of the major groups are discussed. The list of references that follows this section will enable you to pursue the topic to any depth you desire.

Duplicate the text pages. One set is recommended per student. This activity may be completed by individual students as homework or as an in-class assignment. Supplement the text materials with audio-visual material, preserved and live specimens to what ever degree possible. During your discussions of this group, emphasize the diversity in form and function. Train your students to look for the adaptive advantages of the structures and behaviors that they observe. Stress the question: How does the observed behavior or structure help the animal to survive? Plan to allow time for a discussion of the text questions and to expand upon the concepts presented therein.

KEY

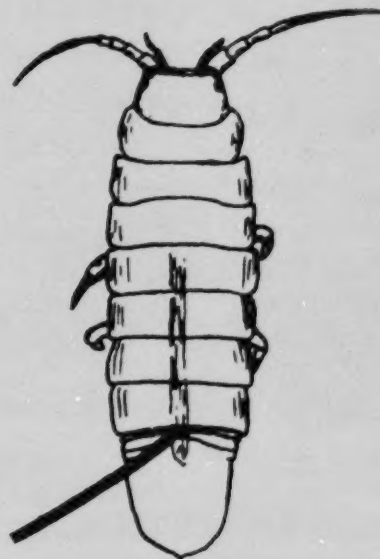
1. Most marine arthropods belong to the Class Crustacea.
2. Most or all of the members of the Crustacea have or do the following:
 - a. an external skeleton (exoskeleton)
 - b. a segmented body
 - c. a body divided into three distinct regions: head, thorax and abdomen
 - d. breathe through gills and/or the body surface
 - e. an open circulatory system
 - f. Liquid wastes are excreted through specialized "green glands."
 - g. well developed eyes, antennae, balancing structures and sensory bristles

Any four of the above common characteristics will suffice to answer the question.

3. Use the above information to place the following animals in their proper group. Write the group name in the space below the animal.



Decapoda



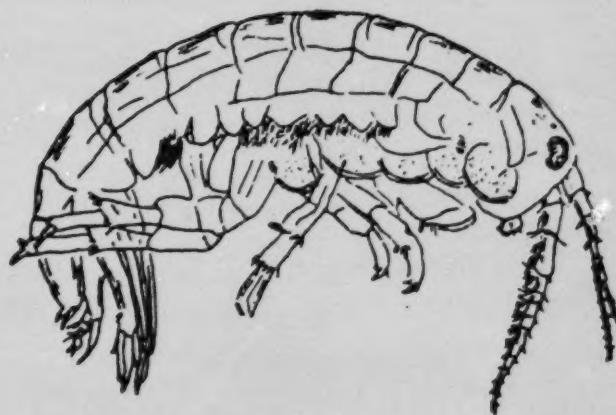
Isopoda



Thoracica



Decapoda



Amphipoda



Isopoda

KEY WORDS

abdomen

abyssal

adaptive radiation

Amphipoda

Arachnida

Arthropoda

Crustacea

Decapoda

exoskeleton

green glands

habitat

Insecta

Isopoda

mollusca

molting

open circulatory system

Thoracica

thorax

ARTHROPODS: They're Everywhere! They're Everywhere!



Crabs, spiders, millipedes, insects, crustaceans: all arthropods. The Phylum Arthropoda is the largest of all phyla, with nearly a million different kinds (species).

Arthropods live in just about every habitat that supports life.

The three principal groups of arthropods are the Crustacea (crabs, shrimp, barnacles), the Arachnida (spiders, ticks, mites, scorpions), and the Insecta (insects). Fortunately for marine scientists, only the crustacea and one group related to the spiders occur in any number in the sea.



Crustacea



Arachnida



Insecta

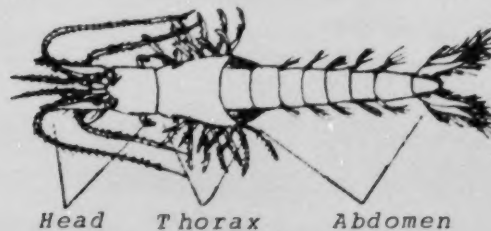
Even without major contributions by the Arachnida and Insecta, the 25,000 or so species of crustaceans living in the sea makes them second only to the molluscs in numbers of species.

1. Most marine arthropods belong to the Class _____.

Crustaceans are highly varied in appearance and life-style. In spite of these differences, there are certain general traits which most arthropods share. All arthropods possess an external skeleton (exoskeleton). The muscles are inside the skeleton. Having a tough outer skeleton provides very good protection for the arthropods. The exoskeleton has its drawbacks, however.

The exoskeleton is probably the factor which has prevented arthropods from becoming very large in size. To become large would mean that the skeleton would become inflexible or too heavy to carry. Furthermore, the structure makes growth a dangerous process. In order to increase in size, the old skeleton must be supplanted (replaced) by a new one. This is done by a process called molting, and before the new skeleton is firm enough to be of much protective value or to allow the animal to move, many of the animals are devoured by predators. A high death rate makes it necessary for most arthropods to produce large numbers of offspring.

The segmented body of the crustacea is usually divided into three distinct regions: head, thorax and abdomen.



All crustaceans breathe through gills and/or the body surface. Oxygen is transported throughout the animal by means of an open circulatory system: the blood is not always contained within vessels as it moves about the body. Liquid wastes are carried to the base of the antennae and excreted through specialized "green glands."

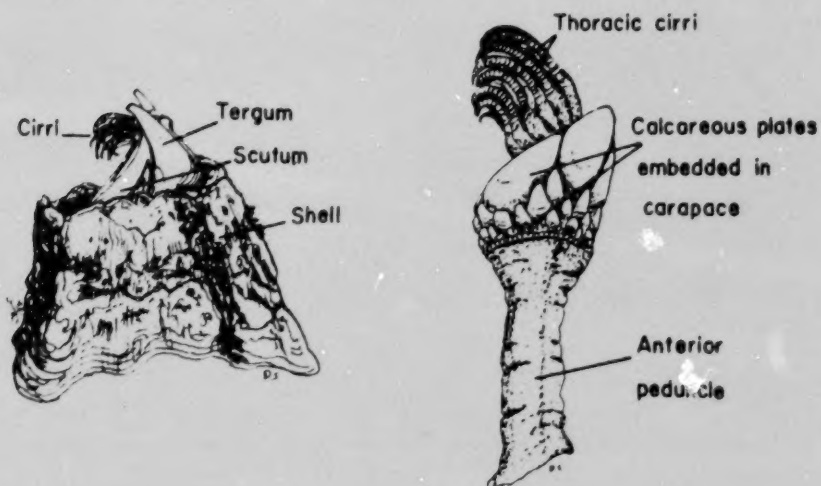
Crustaceans sense their environment through well developed eyes, antennae, balancing structures and sensory bristles. A brain and a double nerve cord transmit the sensory messages throughout the body.

2. Most or all of the members of the crustacea have or do the following:

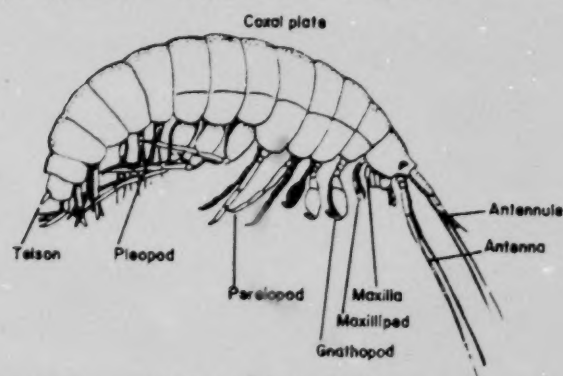
- a. _____
- b. _____
- c. _____
- d. _____

The four most common groups of crustaceans are:

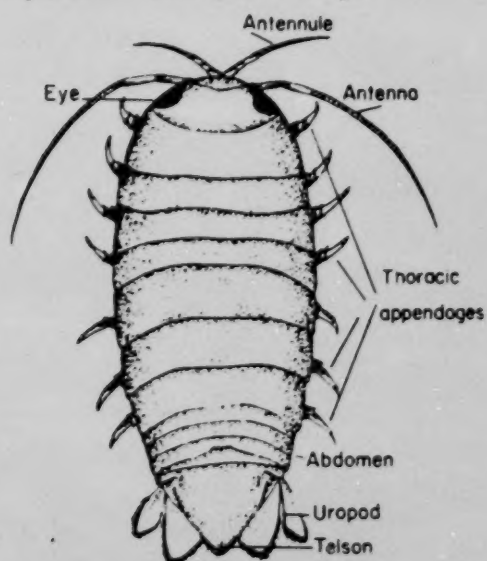
A. Thoracica - the common barnacles



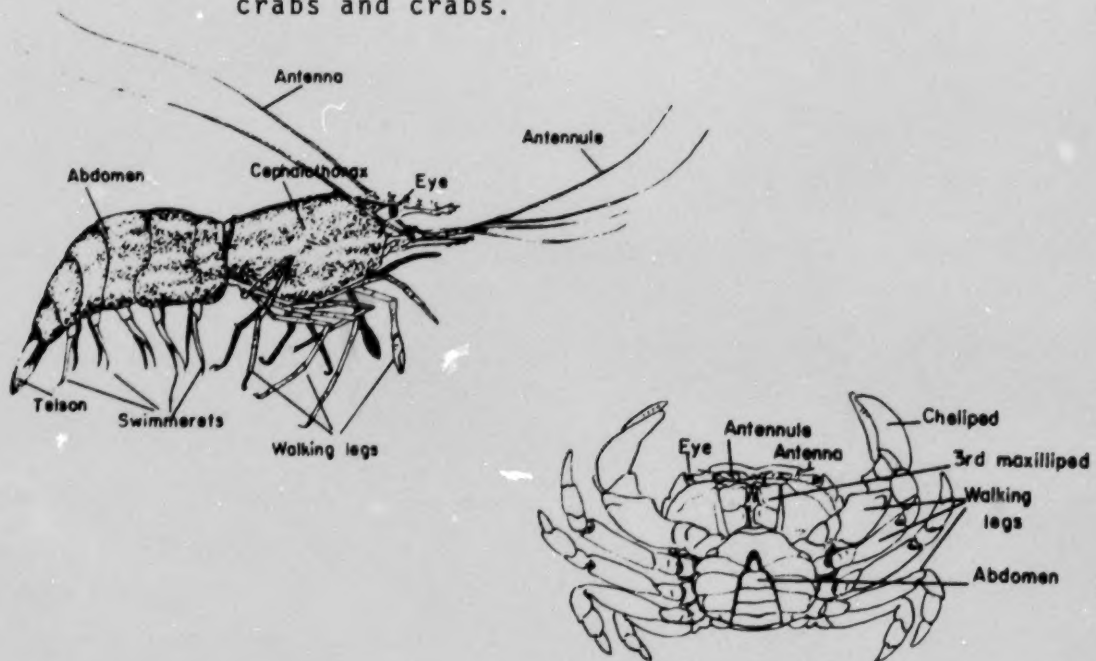
B. Amphipoda - the sand "fleas"



C. Isopoda - the pill bugs



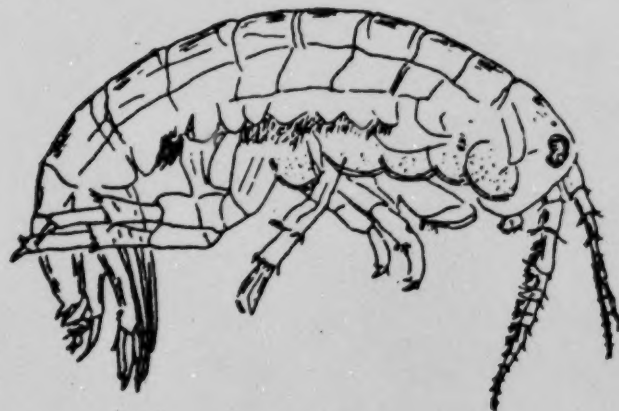
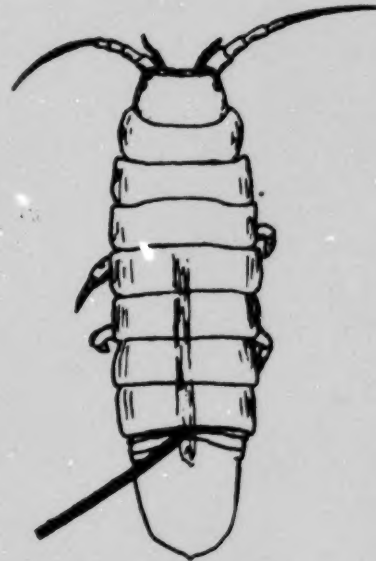
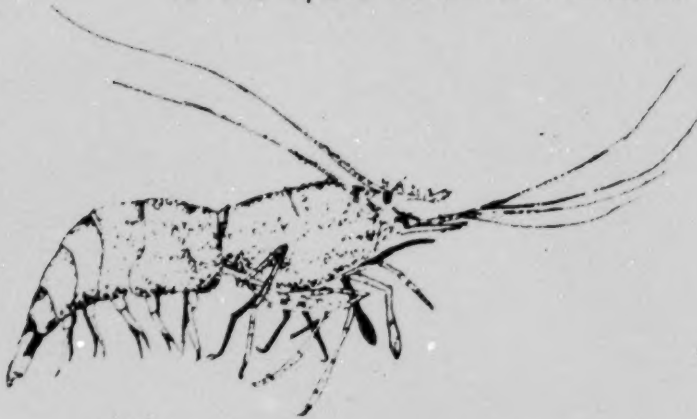
D. Decapoda - the shrimps, ghost shrimps, hermit crabs and crabs.



Crustaceans play a critical role in the life of the sea.

The majority of planktonic animals found in ocean waters are crustaceans. Crustaceans are also well represented on the sea bottom from the intertidal zone to the abyssal depths. Crustaceans range in size from microscopic plankton to giant spider crabs with a leg span of over 3.5 meters (about 11 feet). Many crustaceans are eaten by man. Many more are eaten by fish and shellfish that are then eaten by man. Some species destroy wooden timbers by boring. Others foul the bottoms of ships. In the next activities you will have an opportunity to examine some members of this diverse and interesting group of sea animals.

3. Use the above information to place the following animals in their proper group. Write the group name in the space below the animal.



TEACHER BACKGROUND - Barnacles: Still Hanging On

The lowly barnacle is an interesting creature. This sessile organism costs the shipping industry hundreds of millions of dollars each year because of fouling. In Chile, giant barnacles are prized as food. Microscopic barnacle larvae make up an important component of the zooplankton. In the following laboratory exercise, your students have an opportunity to observe barnacles firsthand.

Duplicate the activity pages. One set is recommended per student. The investigation can best be accomplished by pairs, but larger groups will also work. Barnacles may be readily gathered from the intertidal zone at low tide. Barnacles may be removed from their substrate by using a blunt chisel. You may find it simpler to collect small rocks with their attached barnacles and, in that way, avoid destroying the barnacle in an attempt to remove the animal from its substrate; (The cement which holds the barnacle to rocks often is stronger than compounds that hold the barnacle's shell together). Barnacles may be maintained in salt water aquaria with relative ease. If collecting is a problem, barnacles may be purchased from biological supply houses.

The lab is divided into three sections, which may be performed on successive days, if desired. In the first investigation, a plankton net or fine mesh nylon cloth may be used to collect the larval stages. In the second and third investigations, the two steps of the cirri movement can be difficult to see. As such, the cirri movements to be counted are the complete movement. Your students should have little trouble with the techniques. Circulate through the class as the investigations are being performed. Upon completion of the investigations, plan to provide time for a discussion of the results and techniques, as well as to provide answers to the questions.

If time permits, the investigations of the effect of environmental influences on barnacles may be expanded. For examples, use cold water in place of the warm water in Investigation III. To observe the role of the cirri in securing oxygen, you may substitute boiled sea water for the warm water. Use of distilled water and salt solutions of

different concentrations can be substituted for the warm water to show the effect of changes in salinity on metabolism. The possibilities are limitless.

KEY

Investigating Barnacle Larvae

Text

5. The sketches should resemble the drawings included in the text.
 6. a.-c. Answers depend upon the experimental observations.
- I. Analysis and Interpretation
1. The distribution of barnacles is accomplished during the larval stages. The free floating larvae effectively spread the barnacle population.
 2. There are several possible advantages to the crowding seen in adult barnacles. The crowding may serve to trap water and reduce the effects of drying for intertidal species. Dense aggregations also increase the likelihood of cross-fertilization. It is also possible that the combined beating of numerous cirri may serve to create more substantial currents and move more food and oxygen past the barnacles. Crowding also facilitates reproduction. Your students will probably have other hypotheses.
 3. The most obvious adaptation that helps prevent drying is the operculum, which may be closed. In addition, the impervious shell also resists drying. The barnacle also traps a small amount of water inside when it closes, thereby reducing the effect of any drying by providing additional moisture. Many of the structures and behaviors observed in studying the barnacle relate to protection from dessication.
 4. Hulls fouled by barnacles suffer from increased friction, which slows the speed of the ship and increases the fuel consumption. In the case of wooden hulls, they also provide microhabitats that support other organisms that directly damage the wood.
 5. Taxonomists would argue about the question for a while before classifying barnacles. From the information presented in the text to date, your budding taxonomists should classify barnacles

as follows:

Phylum: Arthropoda
Class: Crustacea
Order: Thoracica

Investigating Barnacle Feeding

Text questions

5. The operculum is covered by two pairs (4) shell plates.
- 6.-9. Answers depend upon experimental observations.

II. Analysis and Interpretation

1. Many factors might cause the barnacle to close its operculum: drying, predators, rest, temperature changes, changes in chemical composition of the seawater (salinity, carbonates, etc.).
2. Answer depends upon the experimental observations, but it would be expected that the barnacles would show a variety of behaviors: e.g., different times of opening, different rates of beating, etc.
3. When the barnacle feeds, the operculum opens. The cirri unroll and extend through the opening. The cirri form a basket. The basket sweeps through the water and traps food particles. The particles are scraped toward the mouth, where they are eaten.
- 4a. The water currents sweep new food carrying water toward the barnacle.
- b. The water currents also carry oxygen to the barnacles as well as sweep away liquid and gaseous wastes.

III. Analysis and Interpretation

1. Graph depends upon the experimental results, but the axes should be properly labeled and the graph should be titled. The graphed results should reflect the figures found in the table in item 6 above.
2. The answer depends upon the experimental results.
3. Within the temperature range your students would normally be working, the relationship would be: increased temperature equals increased rate of beating.
4. The answer depends upon the generalization made in number 3. In this case, the reasonable prediction would be: decreased temperature equals decreased rate of beating.

KEY WORDS

adaptation

axis

barnacles

calcareous

cirri

cross-fertilization

crustacea

cyprid stage

fouling

generalization

hermaphroditic

larvae

mantle cavity

metamorphosis

nauplius stage

operculum

substrate

taxonomists

Thoracica

zooplankton

BARNACLES: Still Hanging On

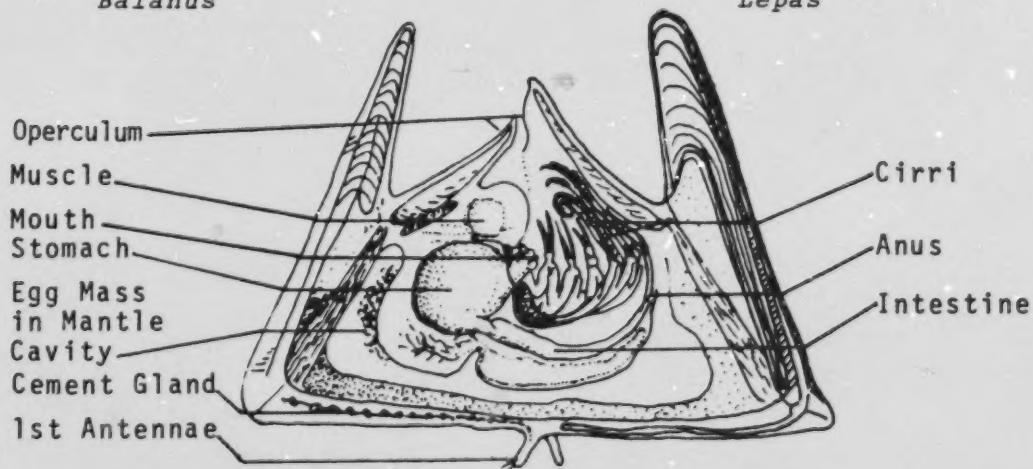
Riddle: How is a whale's back like a ship's hull and a dock piling? Answer: All three are covered by barnacles. Barnacles belong to the Order Thoracica of the Class Crustacea and are found throughout the seas. Barnacles seem to bear little resemblance to other crustaceans. Close observation, coupled with a little imagination, shows that the barnacle is actually a shrimp-like creature living on its back and hiding in a shell. Its feet (cirri) stick up through openings in the shell and are used like paddles to push the food into the mouth.



THE ROCK BARNACLE
Balanus



AN ADULT GOOSE BARNACLE
Lepas



ACORN BARNACLE (part of shell removed
to show animal in retracted position)

In the following activity you will have an opportunity to examine barnacles and observe the effects of various environmental changes on their behavior.

Materials:

live barnacles
finger bowls
petri dish
salt water, cool and warm
dissecting microscope
compound microscope
thermometer
vegetable dye (food coloring)
live brine shrimp (Artemia sp.) or fine fish food or clam bits
watch or timer with second hand
glass stirring rod
eye dropper

Procedure:

1. Obtain living barnacles. Barnacles may be found attached to pilings, rocks, etc. Small barnacle covered rocks may be collected intact or you may remove attached barnacles, being careful not to damage the animal. (A blunt wood chisel is a good collecting tool.)
Keep the barnacles submerged in a bucket of sea water until you can return them to a salt water aquarium in your classroom.

I. Investigating Barnacle Larvae

Barnacles are the only large group of hermaphroditic crustaceans, each individual containing both female and male reproductive organs. Even so, most often cross-fertilization occurs. The eggs of a barnacle are fertilized by the sperm cells of a different barnacle.

The fertilized eggs are retained within the barnacle and hatch within about ten days. The young develop in the mantle cavity until they reach the nauplius stage. At this stage, the nauplius larva escapes and becomes a free living member of the zooplankton.



Nauplius of Barnacle

The six legged nauplius molts each three to five days as the animal changes its form. The mouth and head parts are reduced and the larva develops a bivalve shell resembling a minute clam. The larva now enters the cyprid stage. Cyprid larvae have six pairs of legs and three eyes. They have also developed cement glands that will allow them to become attached.



Cyprid Larva of Barnacle

The cyprid larva settles to the bottom and attaches itself to a suitable substrate (base) where it metamorphoses (changes) into the adult. The six pairs of limbs point upward and the mantle secretes calcareous (made of calcium carbonate, like seashells) plates. For the rest of the barnacle's one to seven year life, the plates grow taller and broader at the base to make room for the animal growing inside.

2. Strain the water in which the barnacles were collected or the water in which they were maintained through a fine mesh nylon cloth.
3. Rinse the cloth into salt water in a petri dish or finger bowl.
4. Observe the water under high power of the dissecting microscope and take samples for observation under the compound microscope.
5. In the space below sketch the larvae you observe:
- 6a. How many pairs of appendages (legs) do the barnacle larvae you observe have?
- b. What stage(s), nauplius or cyprid, of development have you observed and sketched above?
- c. Label your sketches with the appropriate stage name(s).
7. Return the water sample to the salt water aquarium.

I. Analysis and Interpretation:

1. Adult barnacles are permanently attached to the substrate. How, then, does the population of barnacles get distributed?
2. Adult barnacles are often found closely crowded on pilings and other submerged objects. What advantage might adult barnacles derive from being crowded together?
3. Some barnacles are found living in the intertidal zone, where they are exposed to drying and wetting twice every 25 hours. What adaptation helps prevent barnacles from drying out?
4. It has been estimated that the shipping industry alone spends over \$500,000,000 (500 million dollars) per year in correcting damage due to fouling of hulls by barnacles. What is one way in which barnacles cause problems?
5. Taxonomists would place barnacles into which phylum, class and order?

II. Investigating Barnacle Feeding

2. Place several living adult barnacles in a finger bowl of sea water.
3. Center the fingerbowl on the stage of a dissecting microscope and do not disturb until the barnacles become active. (The cirri will begin to move.)
4. Observe the barnacle and in the space below describe how the cirri move.

5. How many plates cover the opening? _____
6. The cirri movement actually occurs in two steps: a slow initial step, in which the plates of the operculum open and the cirri protrude and unroll and; a rapid second step when the cirri are projected forward and withdrawn as water is sieved through the hairs on the limbs.

If possible, time the two steps and record the data below:

initial step: _____ seconds

second step: _____ seconds

7. For the following observations, consider the first and second step as a complete feeding cycle.
 - a. RECORD the water temperature: _____
 - b. Time the number of beats (complete feeding cycles) that occur in sixty seconds.

RECORD: _____ beats per minute.

8. Place a small amount of food on the end of a glass stirring rod or in an eyedropper and offer it to the barnacle. Describe how the barnacle acts in response to the food.

9. Use the eyedropper to gently place a drop of vegetable dye near the portion of the barnacle containing the attached ends of the cirri. In the space below show direction of the water current created by the cirri.

How effective are the cirri in moving water past the barnacle?

10. Return the barnacles to the salt water aquarium.

II. Analysis and Interpretation

1. In nature, what factors might cause the barnacle to close its operculum?
2. Did all of the barnacles observed behave in the same way? If the barnacles' behavior differed, explain how.
3. How does a barnacle feed?
- 4 a. How do the water currents caused by the moving cirri help the barnacle to obtain food?

- b. Of what value might the water currents be to the survival of the barnacle?

III. Investigating the Effect of Temperature on Cirri
Movement

2. Place several living adult barnacles in a finger bowl of sea water.
 - 3 a. RECORD the temperature of the sea water: _____ °C.
Also RECORD the temperature in the table which follows.
 - b. Count and record the number of beats per minute:
_____ beats/minute.
 - 4 a. Obtain sea water which is about 10°C warmer than the water in the finger bowl. Remove about half of the sea water covering your barnacles and replace it with an equal volume of the warmer water.
 - b. Record the temperature of the water: _____ °C.
 - c. Record (here and in the table) the beats per minute: _____ beats/minute.
 - 5 a. Repeat the steps of procedure 4 a-c.
 - b. Record the temperature of the water: _____ °C.
 - c. Record the beats per minute: _____ beats/minute.
 - 6 a. Replace the warm water with fresh cool sea water.
 - b. Record the temperature of the water: _____ °C.
 - c. Record the beats per minute: _____ beats/minute.
- Complete your table.

2. At which temperature did the cirri beat most rapidly?
3. Observe your graph and the graphs of other students in the class. What is the apparent relationship between water temperature and the action of the cirri?
4. Use the generalization you made in number three above to predict what would happen to the rate of beating if you lowered the temperature rather than raised it.

TEACHER BACKGROUND - The Living Crab

Crabs are a familiar and important representative of the Class Crustacea. In the following exercise your students will have an opportunity to observe a living crab. The crab is an ideal laboratory specimen in most areas because:

1. It is easy to keep alive and is relatively available.
2. It is large enough so that the various parts can be seen without the aid of a microscope.
3. It shows outstanding specialization of appendages. Form and function can be easily related.
- 4., If you choose the right kind of crab you can have a very nice dinner after the exercise is completed!

Duplicate the activity pages. One set is recommended per student. Crabs may be obtained from a variety of sources. If you live near the coast you can probably collect your own crabs. Shore crabs are easily obtained by turning over rocks at low tide (please turn all rocks back to their original position). With a little work, Dungeness or rock crabs can be taken with a scoop or crab pot. Be sure to check local regulations for size and number limits and for season length. Crabs may also be obtained from fish wholesalers. A live crab is best but a frozen crab will allow much of the exercise to be completed. Biological supply houses also supply live crabs at a reasonable cost. For example: Carolina Biological Supply, 2700 York Road, Burlington, North Carolina 27215. As a last resort, pet shops often sell hermit crabs for pets. Most of the exercise could be completed using hermit crabs.

Crabs need to be kept moist. They can be entirely submerged in salt water, but they will also do well if they are partly submerged. Crabs have a rather strong grip. Avoid being gripped! Grasp the crab across the back. Watch the action of the pincers. A preview of crab handling is recommended before doing this exercise with your class. Groups of two or three students is ideal. It is best to use small shore crabs. Demonstrate the proper handling methods to the students and observe the handling carefully. Anticipate any

problems you might encounter (squeemish students, loose crabs, etc.) beforehand and be prepared to deal with them if they arise. Plan to spend some time upon completion of the investigation to answer the questions and discuss the activity.

KEY

Questions whose answers are student observations have been omitted from this section.

- 2c. While crab coloration is highly varied, specimens often show countershading - dark on top and light below. It is thought that the light bottom provides a degree of camouflage from animals looking up at the crab with a lighted surface as the background. The dark dorsal side helps the animal blend in with the bottom.
- 3b. The advantage of withdrawing the eye is obvious, it provides protection against loss.
- 5e. Ratios vastly different from one male per one female might arise from many causes: differential fertilization may cause an initial difference; differential mortality at some state of development; sampling or catching procedure that favored the selection of one sex over another; etc. Since it is not possible to provide a "correct" answer, use this question to generate testable hypotheses.
- 7b. The chelipeds function in protection, obtaining food, and locomotion. (Two are required)
- 7c. The next three pairs of appendages are primarily concerned with locomotion.
- 7d. In some species (e.g. the eastern blue crab, some Cancer species) the fourth pair of appendages is modified for swimming.

KEY WORDS

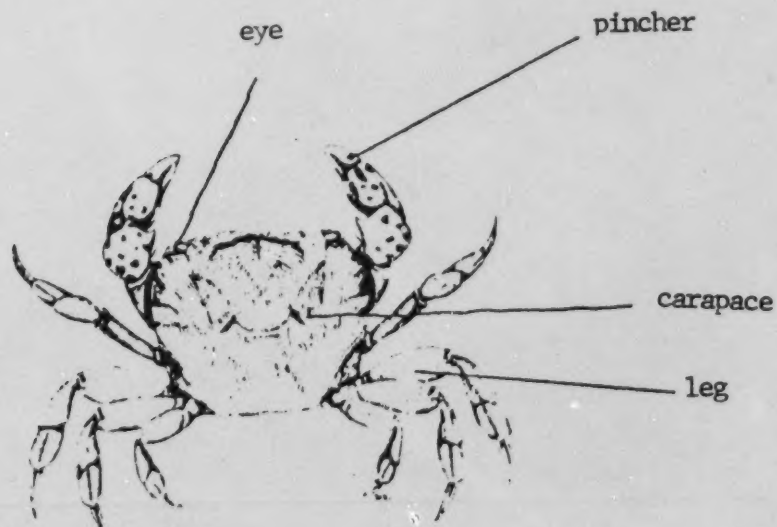
abdomen
 appendage
 apron
 average
 caliper width
 carapace
 cephalothorax

crab
dorsal
estimate
pincher
ratio
stalk
ventral

THE LIVING CRAB



Crabs in trees? Crabs are found everywhere along the sea coasts from the rocky intertidal zone to soft mud bottoms. But in trees? Coconut crabs of the South Pacific are indeed found in trees! These 10 kilogram (about 22 pound) monsters climb palm trees and feed on coconuts. They use their strong pinchers to husk the tough skinned coconuts. Some shore crabs are barely the size of your little finger while the Japanese spider crab from the North Pacific can have a twelve foot leg span. It is easy to see that crabs are a diverse group in both



Hemigrapsis nudus

appearance and in the way in which they live. In the following exercise you will have an opportunity to examine the

structure of a living crab and to observe some of its behaviors.

Materials:

living crab

hand lens or dissecting microscope

finger bowl

salt water

forceps

pencil

ruler

aquarium or other container for holding crabs

1. Observe a live crab in an aquarium or similar container.

Use your observations to answer the following questions:

a. How does the crab move? _____

b. Can the crab swim? _____

c. If your aquarium has a sand bottom, how does the crab dig in the sand? _____

2. Obtain a crab and place it in a finger bowl of sea water.

Use this crab to make the observations necessary to answer the following questions:

a. What color is the dorsal (top) surface of your crab? _____

b. What color is the ventral (bottom) surface? _____

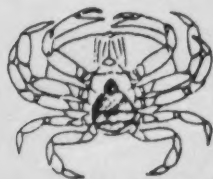
- c. What might be an advantage of the coloring scheme you have observed in your crab? _____

- d. How many appendages (legs, etc.) does your crab have? _____

- e. Which appendages does the crab use in walking?

- f. Is your crab forming any new appendages? _____
If so, which one(s)? _____
- g. The head and soft body of the crab is fused into the cephalothorax. The cephalothorax is completely enclosed in a hard shell. The top of the cephalothorax is called the carapace while the segmented abdominal part of the body underneath is called the apron. In the space below diagram the shape of the carapace.

3. The crab has a pair of well developed eyes, mounted upon moveable stalks. The stalks project from the front of the carapace.
- a. Gently touch the eyestalk with a pencil. What is the response of the crab? _____
- _____
- b. What might be the advantage of such a behavior? _____
- _____
4. Female and male crabs may be easily distinguished by looking at the shape of the abdomen, a shell flap on the ventral side. As you can see from the drawings below, the female crab has a wide apron (abdomen) while the male has a narrow triangular shaped apron.



Female



Male

The ability to sex crabs is important to sport and commercial fishermen alike since crabbing regulations often specify which sex crabs as well as which size crabs may be legally taken.

- a. Look at the shape of the abdomen. What sex is your crab? _____

5. Tally the number of males and females by placing a mark on the blackboard under the proper heading. After the class has recorded all of the information, answer the following questions:

- a. What was the total number of crabs observed? _____
- b. How many are females? _____
- c. What is the ratio of males to females?

(Hint: $\text{ratio} = \frac{\text{Number of males}}{\text{Number of females}}$)

- d. Find the number of males per female by dividing out your ratio in the space below.

- e. Is the ratio close to one male per one female? _____
If not, how might you account for your observations?

6. Use your forceps to gently lower the abdomen. The pairs of appendages are called swimmerets. One pair is present for each abdominal segment except the last. The swimmerets function in swimming and in reproduction.

- a. How many abdominal segments are present? _____
- b. In the space below, sketch the shape of a swimmeret.

- c. In the female crab, the many fine hairs hold the eggs. Are eggs present in your crab? _____
- If so, describe the color, number and size of the eggs. _____
- _____
- _____

7. The crab has five pairs of legs. The first pair bears strong claws or pinchers. Each first leg is called a cheliped. The muscles controlling the legs are anchored inside the body on the inner surface of the shell.

- a. In the space below, sketch one pincher.

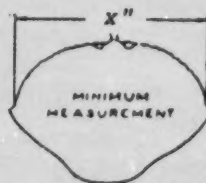
b. What are two functions of the chelipeds?

c. What is the primary function of the next three pairs of appendages? _____

d. Is the fourth pair of appendages identical to the three pairs preceding it? _____

If not, what might be the role of the modifications you observe? _____

8. Crabs are measured across the back (from "point to point") to determine their size. State regulations limit size of the crab that can be kept. This measurement is called the caliper width. Use the drawing below as an aid to determining the caliper width of your crab.



a. How wide is your crab (caliper width)? _____

9. Record the width of your crab on the blackboard in the appropriate space.
- a. How wide is the widest crab in the class? _____
 - b. How wide is the narrowest crab in the class? _____
 - c. Estimate (make an educated guess) the width of the average crab. _____
 - d. Find the arithmetic average by doing the following:
 - 1. add all of the widths
 - 2. divide by the number of crabs measured.

Your answer is the average. Calculate the average in the space below.

- e. How does the calculated average compare with your estimate? _____
10. See how powerful your crab's pinchers are. DO NOT PUT YOUR FINGER IN-BETWEEN THEM. Place your pencil in between the pinchers. Try to lift up the crab using your pencil. Be careful not to lift the crab too high. You only need to see if she is powerful enough to lift her own weight.
- a. Can your crab hold up her own weight with one pincher? _____
 - b. Can you lift yourself up from the ground with only one arm? _____

c. Pound for pound, who do you think is stronger?

11. Return your crab to the saltwater aquarium.

TEACHER BACKGROUND - Getting Started With Prawns

"Getting Started with Prawns" focuses on a Marine Advisory Program Bulletin from the University of Hawaii Sea Grant Program. The activity provides your students with some fundamentals of economics while providing an exercise in critical reading. The answers to the various questions are found in the bracketed sections of the text connected to the questions. This activity will also give your students a brief introduction into some of the things they will have to keep in mind if they plan to start a business of their own.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students as homework or as an in-class assignment. You may elect to have your students work together on the assignment or to meet in groups for a comparison of answers before you discuss the article and provide correct answers to the entire class. Use the approach that will work best with your particular class.

KEY

1. Fixed costs are costs that are the same for a large or small operation.
2. If the drilled well was 400 feet deep instead of 300 feet deep the estimated construction outlay would be:

$$400 \text{ feet} \times \$150.00 \text{ feet} = \$60,000.00$$
3. The total equipment cost in October 1980 would be:

$$\begin{aligned} \$20,700 \times 10\% \text{ for } 1979 &= \$2070.00; \$2070 + \$20,700 = \$22,770 \text{ in } 1979 \\ \$22,770 \times 10\% \text{ for } 1980 &= \$2277.00; \$2277 + \$22,770 = \$25,047 \text{ in } \\ &\text{October of } 1980. \end{aligned}$$
4. Since the stocking level is 70,000 prawns per acre, the value of the gift is:

$$\frac{\$7.50}{1000 \text{ prawns}} \times \frac{70,000 \text{ prawns}}{\text{acre}} = \$525.00 \text{ per acre}$$

5. If you had to purchase brood stock for your entire 10 acre pond, the total start up capital requirement would be:
 $\$525.00/\text{acre} \times 10 \text{ acres} = \$5,250$ plus \$181,300 start up cost =
 a total start up cost of \$186,550.
6. The revised total would be:

Construction Cost	\$108,000	(increase from well)
Equipment Cost	25,047	(increase from inflation)
Other	<u>72,850</u>	(increase due to prawns)
Total	\$205,897	
7. If the wholesale price drops to \$3.50 per pound the expected profit would be:
 $\$3.50/\text{pound} \times 2,250 \text{ pounds per acre} \times 10 \text{ acres} = \$78,750$
 minus \$67,600 expenses = \$11,150 profit
8. If costs rose to \$78,000 per year the break even price would be:

$$\frac{\$78,000 \text{ costs}}{22,500 \text{ pounds}} = \$3.46 \text{ per pound}$$
9. If expenses dropped to \$60,000 the new rate of return would be:

$$\frac{\text{annual profit}}{\text{annual operating cost}} = \frac{\$16,775}{\$60,000} = .28 \times 100 = 28\%$$
10. If the price went up to \$5.00 per pound the annual profit would be:

$$\frac{2,250 \text{ pounds}}{\text{acre}} \times 10 \text{ acres} \times \frac{\$5.00}{\text{pound}} - \$67,600 \text{ operating expense} =$$

$$\$44,900 \text{ annual profit}$$

KEY WORDS

brood stock
 capital
 expenses
 fixed cost
 inflation
 juvenile
 prawns
 profit
 wholesale price
 yield



GETTING STARTED WITH PRAWNS

So you want to go into business for yourself? There's big money in prawns! Or is there? The following article from the University of Hawaii is used by the University Extension Service to generate interest in raising prawns. The article presents a great deal of information in a small amount of space. The questions keyed to various paragraphs are designed to help you find the important ideas and concepts. Skim the article before you begin to answer the questions so that you will have some idea about what the authors are trying to do. Then go back and answer the questions in order. The information needed to answer a given question is found within the bracketed section attached to the question. Good luck and send me an invitation to your "Grand Opening Prawn Sale".

UNIVERSITY OF HAWAII SEA GRANT COLLEGE PROGRAM

MARINE ADVISORY PROGRAM

October 1978

UNIHI-SEAGRANT-AB-79-01



GETTING STARTED WITH PRAWNS

by John M. Shklov and C. Richard Fassler

CAPITAL INVESTMENT & OPERATIONAL COSTS

1. What are fixed costs?
2. What would the total estimated construction outlay be if the drilled well was 400 feet deep? Please show your work.
3. Given a conservative inflation rate of 10% per year what is the expected total equipment cost in October 1980? Please show your work.
4. At an average price of \$7.50 per 1000 juveniles, what is the value per acre of the gift of juvenile prawns from the Anuenue Fisheries Research Center? Please show your work.
5. If you had to purchase your brood stock for your 10 acre pond, what would your total "start-up" capital requirement be?

Costs of constructing and operating a prawn farm vary considerably. For example, it will be more expensive to construct ponds on sloping land than on level land. On the other hand, certain costs are fixed and are the same for a large or small operation. The cost of land will depend on its location and the lease rent. Exact cost figures cannot be provided, but it is possible to estimate how much capital is needed for constructing and operating a 10-acre farm.

Construction cost includes pond design preparation, an access road, a drainage system, and pipes. The cost of these is approximately \$45,000. The cost of digging a well is about \$150 a foot. For an 8-inch diameter well, 300 feet deep, the expense is another \$45,000. (It is important to remember that the depth of a well may range from 100 to 400 feet). Adding the cost of a work and storage shed (\$3,000), the total estimated construction outlay is \$93,000.

Equipment needed includes a 700-gallon per minute, 10-horsepower pump (\$8,000), a harvesting net (\$1,000), a truck (\$7,000), a dissolved oxygen meter (\$700), and miscellaneous items (\$4,000). Total equipment cost is then about \$20,700. Adding this to the construction expense gives a total of approximately \$113,700.

Other operating costs include labor, feed, juvenile prawns, interest on the construction loan, lease rent, electricity, gas, etc. If you are willing to enter into a cooperative agreement with the State, the Anuenue Fisheries Research Center will stock your first 20 acres of ponds free-of-charge for 3 years. If you have more than 20 acres you will have to pay for juveniles for the extra acres on a cost basis. The cost ranges from \$6 to \$10 per 1,000 juveniles. The stocking rate is 70,000 juveniles per acre per year. In return, you will sign a contract that stipulates that you will maintain your ponds according to Anuenue's standards, keep accurate records, and allow your ponds to be used for experimentation. You may sell the prawns and keep the income.

Thus, there is no charge for juveniles and if the cost of leasing land is \$450 per acre per year, operating expenses for the first year of production is approximately \$67,600. The total "start-up" capital for a 10-acre prawn operation is then about \$181,300.

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6. Incorporate your answers to numbers 2, 3, and 5 and give a revised total:

ESTIMATED CONSTRUCTION AND OPERATIONAL COSTS
FOR A 10-ACRE PRAWN FARM

CONSTRUCTION COST \$ 93,000
(access road, drainage
system, pipes, well,
work and storage shed)

OPERATIONAL COST

Equipment 20,700
(pump, harvesting
net, truck, dissolved
oxygen meter, etc.)

Other 67,600
(labor, feed, juvenile
prawns, loan interest,
lease rent, electricity,
gas, etc.)

TOTAL \$181,300

7. If the wholesale price drops to \$3.50 per pound, what is the expected profit?

The next step is to consider what kind of production to expect and what kind of profit can be realized. The current average prawn production is 2,500 pounds per acre per year, with the best farms reaching more than 3,000 pounds. If we take a very conservative figure of 2,250 pounds per acre for the first year and multiply it by the current average wholesale price of \$3.75 per pound, an income of approximately \$8,437.50 per acre or \$84,375 for 10 acres can be expected. Subtracting the annual operating expense of \$67,600 from \$84,375 leaves a profit of \$16,775.

8. There is an error in this passage. To determine the break-even price divide the annual operating cost by the annual yield of prawns in pounds. What would be the break even price if costs rose to \$78,000 per year? Please show your work.

In order to determine the break-even price, divide the annual operating cost by the annual income. The result is that prawns sold at a price greater than \$3.00 per pound will yield a profit.

9. If expenses dropped to \$60,000 per year, what would the new rate of return be? Please show your work.

The rate of return for operating a prawn farm can be calculated by dividing the annual profit by the annual operating cost. This return, 25 percent, can be increased by reducing labor and feed expenses.

Prawns can be wholesaled at the pond site, or sold live in containers to restaurants, stores, or markets.

10. You've decided to open your own drive-in prawn shop to cut out the middle man. If your costs and yield were the same as the estimates in the article but your selling price went up to \$5.00 per pound, what would your annual profit become? Please show your work.

Prawns are often sold live in tanks where customers are allowed to select the ones they wish to purchase. Even at a retail price of more than \$5.00 a pound for the whole animal, the demand has been greater than the supply. Often, the amount available is sold within a few hours.

BIOLOGICAL FACTORS:

The Spiny Skinned Animals - Phylum Echinodermata

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TEACHER BACKGROUND - Superstars and Puzzling Words

Echinoderms are exclusively marine animals, and as with the sponges, they closely resemble no other phyla. Some 6,000 modern species and over 20,000 fossil species have been described. Members of the Phylum Echinodermata have been recorded from the start of the Cambrian Period - some 60,000,000 years ago. The inability of the echinoderms to control the water content of their bodies may be a principal reason that they have never occupied a fresh water niche.

Some of the most beautiful and eye catching organisms of the neritic region belong to the Phylum Echinodermata, which includes the starfish, the brittle stars, the sea cucumbers, the sand dollars, the sea urchins and the sea lilies. The following characteristics are common to nearly all echinoderms (see Figs. 1, 2, 3 and 4 for anatomy):

1. The symmetry is radial; i.e., the organism can be cut in a number of planes to yield similar halves.
2. The skeleton is of mesodermal origin and is covered by an epidermal layer.
3. The gut is usually complete. (A few forms lack an anal opening.)
4. There is a spacious true coelom (body cavity lined on both sides by mesodermal tissue).
5. The circulatory system is almost functionless. Circulation is carried out by the coelom and water-vascular system.
6. A water-vascular system complete with tubed feet is present in most groups.
7. Respiration and excretion take place by diffusion through the body wall via papulae leading from the coelom, through the tube feet, or through a respiratory tree (present only in the cucumbers).
8. Movement in most cases is accomplished by tube feet and occasionally by body contraction.

9. The nervous system is poorly developed and movement is almost always a very slow process. (Some of the brittle stars can swim by thrashing the radii.)
10. Sexes are separate and in most cases fertilization is external and motile, ciliated larvae are produced.

The following classes of echinoderms are recognized:

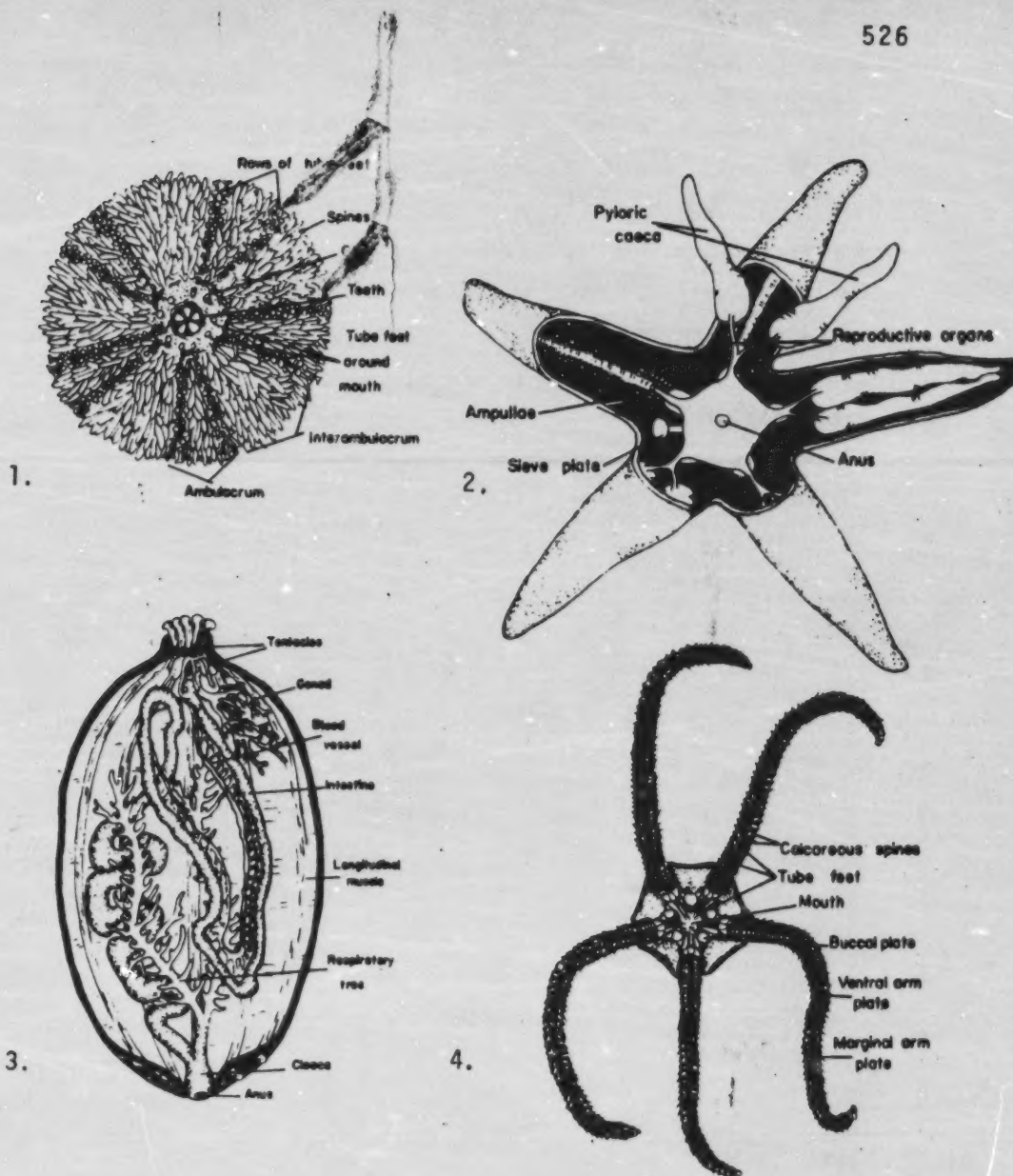
Class 1. Asteroidea - The starfish with five or more solid radii which blend with the central disc.

Class 2. Ophiuroidea - The brittle stars with five jointed radii clearly demarcated from the central disc.

Class 3. Holothurioidea - Sea cucumbers - soft bodied, elongate animals without spines and without radii.

Class 4. Echinoidea - Sea urchins and sand dollars - spiny, spherical or disc-shaped animals without radii.

Class 5. Crinoidea - Sea lilies and feather stars - The mouth opens upwards and is surrounded by branching radii. Only one crinoid is included in this book, since they are not commonly represented in the intertidal region.



External anatomy of a sea urchin (upper) and internal anatomy of a cucumber (below).

Internal anatomy of a starfish (upper) and external anatomy of a brittle star (below).

From; Flora, Charles J. and Eugene Fairbanks, 1977. The Sound and the Sea. The Washington State Department of Printing. 476 pages.

Duplicate the text and activity pages. One set is recommended per student. The vocabulary activity, "Puzzling Words," is best assigned simultaneously with "Superstars," since it reinforces the vocabulary introduced therein. The activity may be accomplished by individual students and may be completed as homework or as an in-class assignment. Before you discuss the activity and provide answers, you may wish to have members of the class meet in small groups to discuss their results. As always, use the approach that works best with your particular class.

KEY

1. r a d i a l S y m m e t r y
2. o P h i u r o i d e a
3. e c h I n o d e r m a t a
4. c e N t r a l d i s c
5. s Y m b i o t i c
6. t e S t
7. e n d o s K e l e t o n
8. s e s s I l e
9. r e g e N e r a t e
10. e x t e r N a l
11. t u b e f E e t
12. g o n a D s
13. r A y s
14. c r i N o i d e a
15. p a r a s I t i c
16. s e a c u c u M b e r s
17. s e a s t A r s
18. z o o p L a n k t o n
19. o s S i c l e s

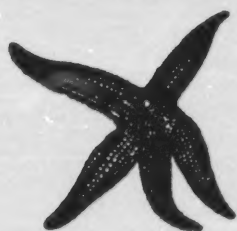
KEY WORDS

Aristotle's Lantern
Asteroidea
beche de mer
calcareous
central disc
Crinoidea
Echinodermata
Echinoidea
endoskeleton
eviscerate
external fertilization
gonads
Holothuroidea
larvae
Ophiuroidea
ossicles
parasitic
radial symmetry
rays
regenerate
sea cucumbers
sea lilies
sea stars
sea urchins
sessile
symbiotic
test
trepang
tube feet
water-vascular system
zooplankton

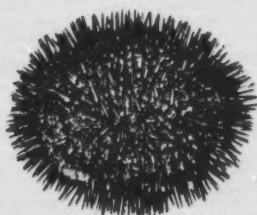
SUPERSTARS



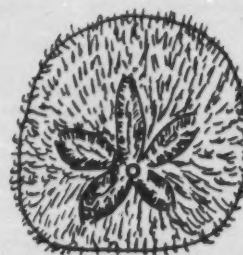
Spiny-skinned animals have been around for a long time - about 60,000,000 years. Who are these "spiny-skinned animals"? The echinoderms (Phylum Echinodermata = Greek for a spiny animal + skin) are exclusively marine and include the sea stars (starfish), sea urchins, sand dollars, sea cucumbers and sea lilies.



Sea Star



Sea Urchin



Sand Dollar



Sea Cucumber



Sea Lily

The members of the Phylum Echinodermata share several common features:

1. The adult animal is radially symmetrical; the animal can be cut in a number of planes and yield similar halves.
2. They possess a supporting endoskeleton located just below the skin.
3. Most have a complete digestive system including two openings (a mouth and anus).
4. A water-vascular system with tube feet aids in locomotion and circulation.
5. Males and females are separate organisms and shed either sperm or eggs into the water (external fertilization) to produce ciliated larvae, which develop as members of the zooplankton.

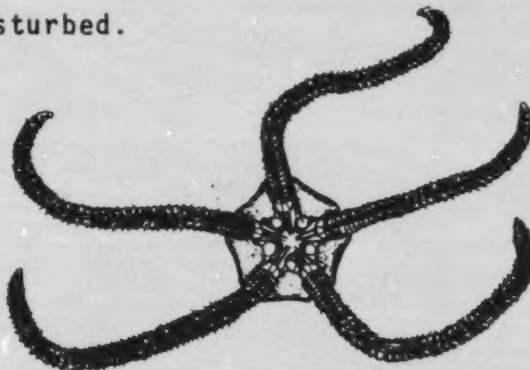
Taxonomists usually divide the echinoderms into five classes:

Class 1. Asteroidea - the sea stars with five or more solid rays (arms) which blend with a central disc. In this group, the tube feet are found on the lower surface, while spines cover both the upper and lower surfaces.



Class 2. Ophiuroidea - the brittle stars, with five jointed rays (arms) clearly demarcated from the central disc. Brittle stars lack tube feet and move by wriggling their arms. The name, brittle star, refers to the tendency of the arms to fragment when the organism is disturbed.

Brittle
Star



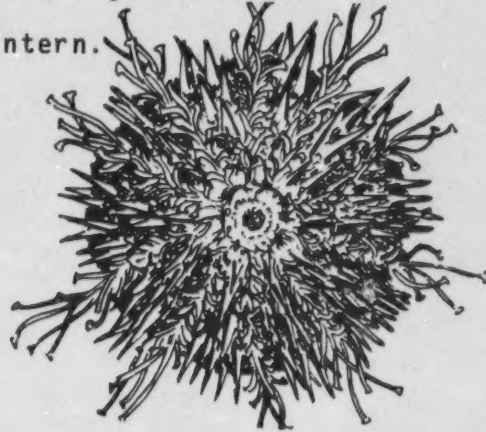
Class 3. Holothuroidea - the sea cucumbers, soft bodied, elongated animals without spines and without rays. In the sea cucumbers, the calcareous skeleton takes the form of loose, disconnected spicules and plates called ossicles. Unlike the sea stars, the ossicles in the sea cucumbers are not paired to form a rigid skeleton.



Sea Cucumber

Class 4. Echinoidea - the sea urchins and sand dollars are spiny, spherical or disc shaped animals without rays. The body is enclosed in a calcareous box called the test. The test is a special type of endoskeleton. The mouth consists of an unusual five-toothed grinding device called Aristotle's Lantern.

Sea Urchin



Class 5. Crinoidea - sea lilies and feather stars are sessile (attached) plant-like forms in which the mouth opens upward and is surrounded by branching rays. They are filter feeders and are most abundant in tropical waters and the deep sea.

Sea Lily



Echinoderms are the only major phylum in the animal kingdom in which there are no parasitic species. In addition, symbiotic relationships (those in which two species interact to the benefit of one or both) are few. The echinoderms are Nature's "loners."

Few echinoderms find their way to the table for use as human food. The ripe gonads (reproductive organs) of sea urchins are an expensive delicacy in Japan where they are eaten raw or cooked. The body wall of the sea cucumber is given the elegant name of "beche de mer" (not so elegant if you translate it from the French as "worm of the sea") or trepang. Preparation involves dropping the cucumber in boiling water. The shock causes the animal to eviscerate ("throw up") its internal organs, leaving behind an intact body wall. The body wall is then dried and sold as a delicacy for use in soups.

Oystermen ("oyster fishermen") continually wage war on the sea star. Sea stars are predators on oysters and can cause a considerable economic loss to the oystermen. At one time a standard practice was to dredge up the sea stars, cut them up into pieces and throw them overboard. ("That'll show 'em.") Unfortunately, any piece of a sea star with a piece of the central disc still attached can regenerate an entire new organism. The poor oystermen were multiplying their problem. In some areas, oystermen still gather sea stars by dragging the sea bottom with a large mop-like device that entangles its fibers onto

the sea stars. The captured sea stars are dealt with in a manner other than cutting them up and throwing them overboard!

PUZZLING WORDS



Using the clues at the bottom of the page, complete the spelling of each word.

1. _ _ _ _ _ S _ _ _ _ _
2. _ _ P _ _ _ _ _ _ _ _
3. _ _ _ I _ _ _ _ _ _ _
4. _ _ _ N _ _ _ _ _ _ _
5. _ _ _ Y _ _ _ _ _

6. _ _ _ S _ _ _ _ _
7. _ _ _ K _ _ _ _ _
8. _ _ _ I _ _ _ _ _
9. _ _ _ N _ _ _ _ _
10. _ _ _ N _ _ _ _ _
11. _ _ _ E _ _ _ _ _
12. _ _ _ D _ _ _ _ _

13. _ _ A _ _ _ _ _
14. _ _ _ N _ _ _ _ _
15. _ _ _ I _ _ _ _ _
16. _ _ _ M _ _ _ _ _
17. _ _ _ A _ _ _ _ _
18. _ _ _ L _ _ _ _ _
19. _ _ S _ _ _ _ _

CLUES:

1. Adult echinoderms can be cut in a number of planes and yield similar halves. They have _____ (two words)
2. This class contains the brittle stars.
3. This phylum name means "spiny skinned."
4. The rays of the sea star are attached to this structure.
5. Few echinoderms engage in _____ relationships.

6. The calcareous box which encloses the sea urchin
7. A supporting structure located just below the skin
8. Attached
9. Sea stars can _____ new body parts if a piece of the central disc is still attached.
10. Fertilization in the echinoderms is _____.
11. These structures are part of the water-vascular system and aid in locomotion.
12. Reproductive organs
13. Sea star arms
14. This class contains sessile filter feeders.
15. The Echinodermata is the only major animal phylum without any _____ members.
16. These animals belong to the Class Holothuroidea.
17. These animals belong to the Class Asteroidea.
18. Ciliated echinoderm larvae are members of the _____.
19. In the sea cucumber, these spicules and plates are disconnected.

TEACHER BACKGROUND - Dealing With Salt

Marine animals must constantly deal with the fact that they are surrounded by a salt solution which has a direct effect on the their ability to survive. "Dealing With Salt" provides your students with additional information regarding osmoregulation in marine animals. Osmoregulation is the process by which animals and plants deal with the movement of water into and out of their cells.

Molecules tend to move from areas of high concentration to areas of low concentration until an even distribution is reached. This movement is called diffusion. Diffusion occurs because of the random movement of molecules. In living organisms, a special type of diffusion called osmosis takes place. The membranes of animal and plant cells readily allow water to pass through but frequently hold back or retard the passage of larger molecules including salts. Under normal conditions, the concentration of salts on both sides of these membranes is the same. Water molecules pass randomly in and out of the cells, and, on the whole, as many molecules pass in as pass out.

If the concentration of salts inside a cell is greater or less than the concentration on the outside, the cell may be in trouble. The side of the membrane that has less salt also has proportionally more water molecules. In other words, this side of the membrane has a higher concentration of water. Since the water can readily pass through the membrane, it will gradually diffuse, as described above, from the more concentrated side to the less concentrated side. The salts, however, being unable to readily pass through the membrane, stay where they are, causing the water molecules to continue to diffuse across the membrane.

If the liquid inside of an organism's cells is saltier than the water around them (for instance, if an animal accustomed to living in salt water is suddenly immersed in fresh water), water will pass into the cells until the cells swell and burst. If the liquid inside of the cell is less salty than the outside (as when a fresh water animal is placed in salt water), water will flow out of the cells until the cells dehydrate and shrivel up.

Many marine invertebrates have little trouble maintaining salt-and-water balance as long as they remain in normal salt water. Lacking any well-developed excretory organs, they exchange waste products, water, and salt with the surrounding water directly across their surface membranes. Their body fluids are essentially isosmotic (having the same osmotic concentration) with the salt water. This means they neither take in nor lose much excess water.

If these animals move into the brackish water of an estuary, however, they will immediately begin to gain water or lose salts, until their body fluids have the same salinity as the surrounding water. They will not normally survive long under such conditions.

Some animals are able to maintain their salt-and-water balance even if the surrounding water has a higher or lower concentration of salts. These organisms are capable of osmoregulation. By actively moving salts or water across their surface, gills, or excretory organ membranes against the osmotic gradient, they can keep their body fluids at a constant concentration. Osmoregulation requires an expenditure of energy, and the amount of energy usually increases with the osmotic gradient.

Organisms with little or no osmoregulatory abilities remain isotonic with the surrounding solutions. In other words, if the salinity outside increases, the salinity within the animal or plant also increases. Organisms with high osmoregulatory abilities maintain their body fluids at or near a constant level. The internal salinity remains constant inspite of changes to the external environment.

Additional information on osmoregulation in marine animals may be obtained by consulting the references noted at the end of this section.

Duplicate the activity pages. One set is recommended per student. While shore crabs and starfish work well, you may carry out this experiment with nearly any aquatic organism. You may also increase the range of salinities (e.g. from fresh water to greater

than 40 ppt) but you should conduct some trial tests to determine how long your experimental animal should be immersed in each solution before weighing. Obviously, it is wise to avoid salinities that might subject your specimens to undue risk of mortality. You may wish to organize the class into teams. Have each team measure the osmoregulation of a different species and compare the results. Carry out the experiment on more than one individual of each species to get accurate results. To save class time, set up three aquaria and fill each with water having a different salinity. Students will simply weigh the animal and drop it into the proper aquarium. Be sure to mark the animals so they can be distinguished if more than one individual of a species is used. Allow time upon completion for a discussion of the procedure and to evaluate the results and provide answers for both questions from the class and from the activity.

To make the solutions required for this experiment, mix the amount of salt in grams equal to the salinity of the solution you wish to obtain with 1000 ml of distilled water for each liter of solution you need. For example, to get a solution of 30 parts per thousand, mix 30 g of salt in one liter of distilled water.

You can also dilute natural sea water with distilled water or add salt to get the proper salinities. For example, mix two parts sea water (35 o/oo) with one part tap water to make a water solution of about 24 o/oo. The salinities of the solutions can then be measured using one of the methods described in this book. For the purposes of most student studies, use the simple hydrometer method described in "Calculating Salinity from Density."

Aquarium Systems, Inc., 33208 Lakeland Boulevard, Eastlake, Ohio 44094, makes a seawater mix called Instant Ocean Synthetic Sea Salt. Instructions for mixing this salt to different salinities come with the package.

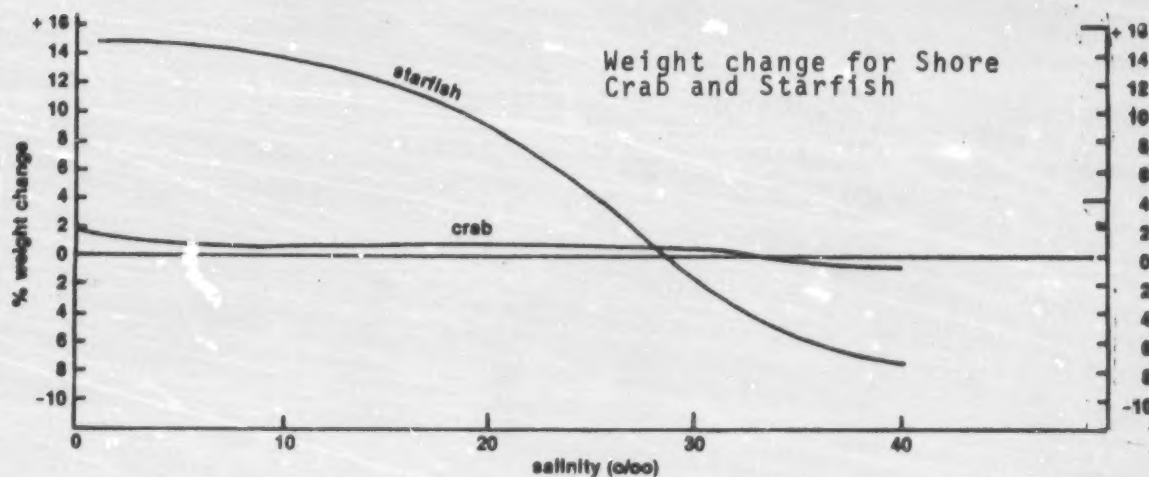
KEY

Text questions

1. Since the water is without salts, the inside and outside concentrations will never equal as long as the jellyfish remains intact.
2. The jellyfish will swell and eventually burst.
3. The shrinking of the jellyfish will stop when the salt concentration on the inside equals that of the water surrounding the jellyfish.
4. Osmoregulation regulates the water movement into and out of living cells.
5. Large weight changes indicate poor osmoregulation because they indicate a large movement of water into or out of the living cells. Good osmoregulators would maintain a constant weight because little net movement of water would occur.

Analysis and Interpretation

1. Answers depend upon the experimental results.
2. While the specific answers depend upon the experimental results, a typical graph might look like the following:



3. a. Answer depends upon the experimental results.
- b. While the answer depends upon the experimental results, the salinities the animal is best able to tolerate are probably those at which it is normally found. At these salinities the animal will lose or gain the least amount of weight.

4. a. Answer depends upon the experimental results.
 - b. There are two major classes of possible reasons for any of the differences observed:
 1. errors of measurement (misrecording, weighing errors etc.)
 2. physiological differences between different animals of the same species (e.g. due to age, genetics, temperature, etc.)
5. a. Answer depends upon the experimental results.
 - b. While the answer depends upon the experimental results, the animal with the smallest weight changes is the best osmoregulator for the reasons discussed above.
 - c. This is a difficult question to answer with accuracy based upon experimental results alone. The animal with the highest ability to osmoregulate could theoretically deal with the changing salinities of the intertidal zone. In reality, other factors also influence where an animal can live. It is also worth noting that some animals from the intertidal are very poor osmoregulators but have a very high tolerance to changes in internal salt concentration. While there may be no "right" answer for this question, it can serve as a basis for discussion of the concepts involved in osmoregulation and survival.
6. The sea star collected from the intertidal zone and placed in a freshwater goldfish tank will gain weight because there will be a net movement of water into the sea star. The sea star will swell and death will likely result because of the sea star's poor osmoregulatory abilities.

KEY WORDS

concentration
dehydration
intertidal zone
osmoregulation
osmosis
percentage weight change
salinity
tolerance
water balance

Additional Information:

Kinne, Otto. 1967. Physiology of estuarine organisms with special reference to salinity and temperature: general aspects. In Lauf, G., ed. Estuaries. Publication No. 83, American Association for the Advancement of Science, Washington, D. C.

Krogh, August. 1939. Osmotic Regulation in Aquatic Animals. Dover Publications, Inc., New York.

Lockwood, A.P.M. 1962. The osmoregulation of crustacea. Biological Review 37:257-305.

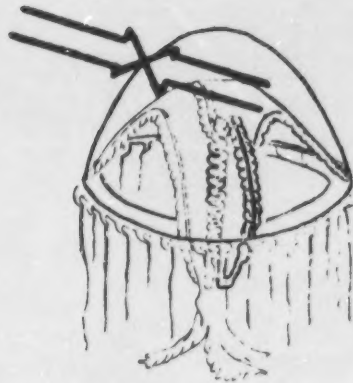
Vernberg, W. and F. J. Vernberg. 1972. Environmental Physiology of Marine Animals. Springer-Verlag, New York.

DEALING WITH SALT



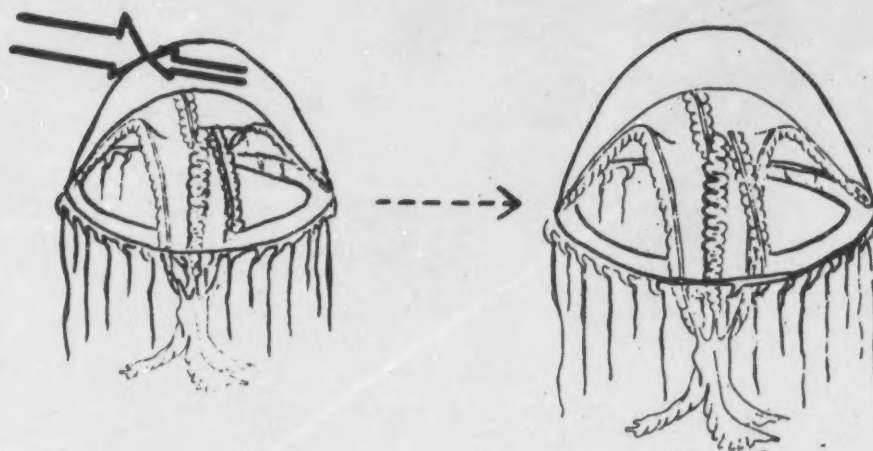
Animals and plants that live in the ocean are affected by the salt concentration of sea water. Animals and plants differ in their ability to tolerate salinity and changes in salinity. Some organisms can withstand a wide range of salinities and can tolerate the large variation found in estuaries, tide pools, salt marshes and brackish areas. Other organisms find a small change in salinity intolerable. All animals and plants have a limit to their tolerance.

How does salinity affect living things? Living cells are largely water with a few dissolved salts and other materials. The materials inside the cell, for the most part, stay there. Water, however, can move into and out of the cell. How is this important? In living cells the water tends to move into or out of the cell until the concentration of salts, the "salinity", inside the cell equals the concentration of salts outside the cell. What does this mean? Let's look at a jellyfish and see. Our jellyfish is floating peacefully in the sea. The salt concentration within its cells is equal to the salt concentration in the water around it. The same amount of water enters its cells as leaves them.



WATER IN = WATER OUT

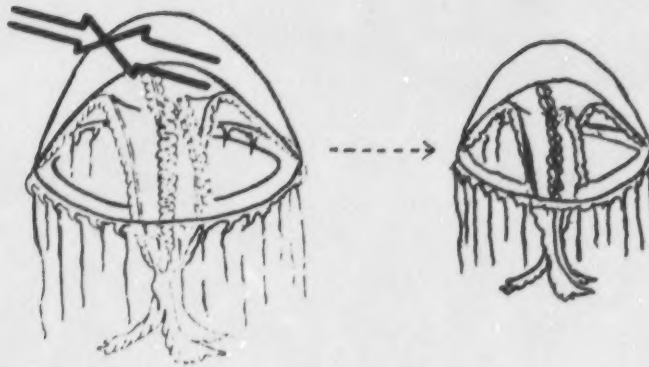
Poor jellyfish! It's collected by Mr. Outofit's oceanography class. Mr. Outofit places the jellyfish in a freshwater aquarium. The salt concentration within the cells of the jellyfish is now greater than the salt concentration in the distilled water of the aquarium. The salt can't move out of the jellyfish. In an effort to equalize the concentrations, water begins to move into the cells of the jellyfish. The concentration of salts in the cells is reduced but it's still higher than in the water. More water moves into the jellyfish and the jellyfish begins to swell.



WATER IN IS GREATER THAN WATER OUT

1. Will the concentration on the outside ever equal the concentration on the inside of the jellyfish?
2. What will eventually happen to our jellyfish?

Mr. Outofit is panicked! Thinking quickly he grabs the jellyfish and moves it into a tank of salt water. Unfortunately for our jellyfish, the salt concentration is 70 parts per thousand (o/oo) about twice what it's used to. How can the inside and outside concentrations be made more equal? This time water moves from the jellyfish into the water. This movement of water makes the salt inside of the cells more concentrated and makes the outside water slightly less concentrated. Our poor jellyfish begins to shrink as it loses water. This shrinking is called dehydration.



WATER IN IS LESS THAN WATER OUT

3. When will the shrinking of our jellyfish stop?

The movement of water into and out of cells is called osmosis. In real animals the situation is more complex than that shown above. The body fluids of most marine organisms are just as salty as sea water. As a result, they have no problem maintaining their salt balance. If the salinity of the surrounding waters changes, the organism must adjust or die. Some organisms are unable to control or regulate their salt-and-water balance. They quickly lose or gain water and die if placed in water having a salinity to which they are not adapted. Other organisms are able to control their water content by a variety of mechanisms including drinking water to make up for water loss or excreting water in their urine to get rid of excess water. These mechanisms for regulating the amount of water passing by osmosis through their body membranes play a role in a process called osmoregulation.

4. What does "osmoregulation" regulate?

In the following procedure, you will weigh an organism before and after it has been immersed in water baths having different salt concentrations. Large weight changes will indicate poor osmoregulation. Small weight changes will indicate good osmoregulation.

5. WHY are large weight changes an indication of poor osmoregulation?

Materials:

living marine animal (e.g. shore crab, sea star)

paper towels

balance

fingernail polish

labeled containers of varying salinities (40 o/oo;
30 o/oo and 20 o/oo)

salt water aquarium or holding tank

Procedure:

1. Obtain a crab or a sea star. Blot the animal as dry as possible with paper towels. Weigh the animal and RECORD this initial weight here and in table 1.
_____ grams.
2. Use fingernail polish to put a distinctive mark on the animal so that you will be able to recognize it if the animal gets mixed up with others.
3. Place the animal in a container or aquarium with water having a salinity of 40 o/oo. After 15 minutes, remove the animal, blot it dry, and reweigh it. RECORD the weight here and in table 1. _____ grams.

4. Repeat this procedure using water having salinities of 30 o/oo and 20 o/oo. In the table, RECORD the weight of the animal after it has been immersed in each solution.
5. When you are finished, return the animal to the holding tank.

TABLE 1

	SALINITY	WEIGHT
initial	_____	_____
	<u>40 o/oo</u>	_____
	<u>30 o/oo</u>	_____
	<u>20 o/oo</u>	_____

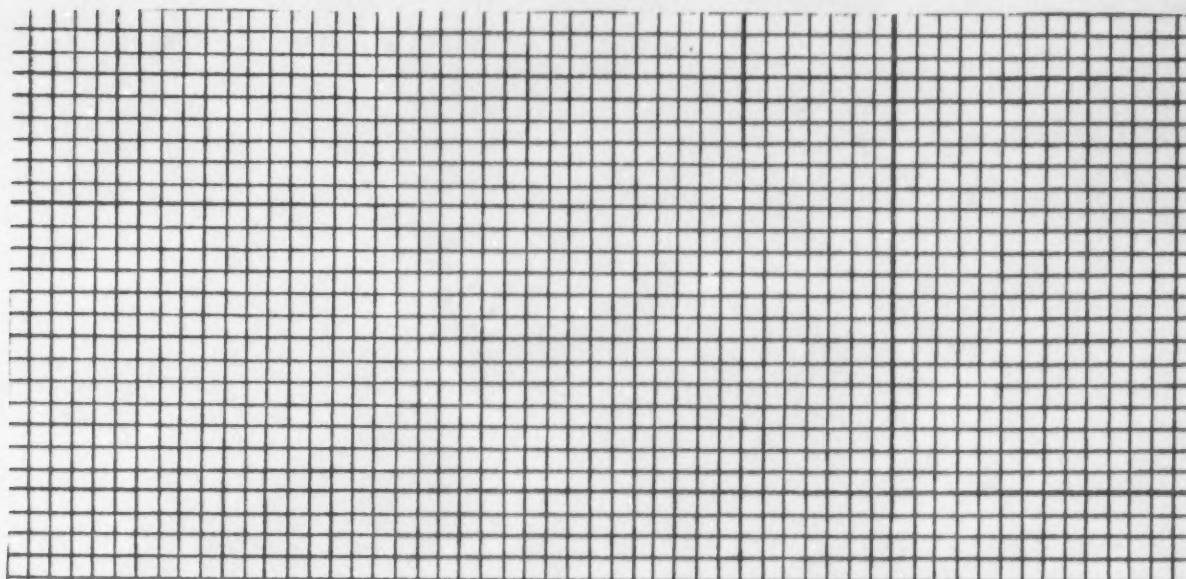
Analysis and Interpretation:

1. Determine the percent weight loss or gain in the animal in each water solution. This is easy:

$$\text{weight change} = \frac{\text{change in weight}}{\text{beginning weight}} \times 100$$

The change in weight is the weight at the end of a given trial minus the beginning weight (the weight found in step 1).

2. Plot the percentage weight change versus salinity on the grid below. Plot the percentage weight change on the vertical axis. Label the axis and give your graph a title.



3. Use your graph to answer the following questions:
 - a. Does the animal seem to be able to regulate its water balance at different salinities? (Hint: The better an animal is able to regulate its water balance, the smaller weight changes are).
 - b. What salinities do you think the animal is best able to tolerate? Explain your choice.
4. Compare your graph to those of other students who used the same animal.
 - a. Did other students find the same results?
 - b. What are two possible reasons for any differences you observe?
 - 1.
 - 2.

5. Compare your graph to those of other students who used different animals.
 - a. Did the curves for the other animals have the same shape?
 - b. Which animal studied is the best osmoregulator? Explain your reasoning.
 - c. Which animal would you most likely find in the intertidal zone? Explain your choice.
6. What is likely to happen to a sea star collected from the intertidal zone and placed in a freshwater goldfish tank? Why?

TEACHER BACKGROUND - "Starfish Threaten Pacific Reefs" - Three Level Guide

The population explosion of Acanthaster planci, the crown-of-thorns starfish, has received much attention and caused widespread concern. The following article gives an overview of the problem and some possible causes of same. The article may be used to relate echinoderm biology to "real world" concerns.

The three level guide presented here is one way to aid students in comprehending reading material. Three level guides are based on what seems to be the general agreement that comprehension can take place at different levels of cognition. Harold L. Herber has called these levels 1) literal; 2) interpretive; and 3) applied. With the exception of the literal level, each level requires the product of the previous level or levels in order to function. The literal level of comprehension produces knowledge of what the author said. We all recognize that it is quite possible to identify and even repeat what an author has said without understanding what the author meant by his statements. The interpretive level of comprehension depends upon the reading performed at the literal level but carries the process a step further. At this level the reader derives meaning from what the author has said. The meaning is determined by the way the reader perceives the intratext relationships. The applied level of comprehension takes the product of the literal, (what the author has said) and the interpretive (what the author meant by what he said) and applies it in some practical or theoretical exercise. At this level the reader is using his past experiences and knowledge to produce new ideas which extend beyond those immediately identifiable in the reading selection. It must be born in mind that the level at which a person reads does not reflect upon her intelligence and that the level can change as the material changes. The most advanced engineers and scientists often read at the literal level if they cross into other disciplines. When we read materials from an area with which we have little familiarity, our level of comprehension goes down. Your students are no exception to this observation. The three level guide is a device used to improve a person's comprehension by focusing on important concepts at each of the three levels. The three level guide can be used with any material and is readily

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constructed. For aid in this regard please see:

Teaching Reading in the Content Areas. 1970. Harold L. Herber.
Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 296 pages.

Duplicate the pages of the three level guide. One set is recommended per student. Spend a few minutes describing what is expected of the student. Suggest that the students read the statements in the three level guide before they read the article. In this way, the statements serve as a preview and your students will be looking for and expecting to see certain concepts. You may elect to have your students compare their answers by meeting in small groups. The process of resolving differences in opinion can be very instructive. Upon completion of the reading and the three level guide, discuss the guide by reference to the article. It is sometimes helpful to have your students note the page number and paragraph number where they found evidence supporting or refuting the statements in the guide. You can require your students to provide this information or you can offer extra credit for those that include it. Choose the technique that most appeals to you and best fits the needs and skills of your class.

KEY WORDS

Acanthaster placi

cause
coral
crown-of-thorns starfish
dredging
ecology
effect
fluctuate
hypotheses
paraphrased
reef
scientific method
triton

KEY

"STARFISH THREATEN PACIFIC REEFS" - Three Level Guide

Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those that you believe say what the author actually said or paraphrase what the author said in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference. Also, be ready to explain what is inaccurate about the statements that you do not check.

- ☒ 1. Coral-killing starfish are destroying living reefs that shelter coastlines from the continual pounding of the sea.
- ☐ 2. Acanthaster planci may be used to control a population explosion that threatens coral reefs.
- ☒ 3. Scientists are following the spread of the crown-of-thorns starfish.
- ☒ 4. A major tactic in dealing with the crown-of-thorns starfish involves hunting and killing of the animals by man.
- ☐ 5. Dead reefs pose few problems to the islands they surround.
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- ☒ 9. Pollution may have an effect on coral reef growth.

Directions: Now compare your answers with those of others in your group. If there are any differences, find the page and paragraph that support your answer and write them next to the statement in question. When you finish your discussion, go on to the next level.

Level II. Directions: Science deals with causes and effects. Effects are the visible things brought about by a cause. They are the results. The cause produces the effect. Most of the statements you have checked in Level I are either cause statements or effect statements. Write the numbers of those statements which are cause statements in column A and the numbers of those statements which are effect statements in Column B. Be ready to justify your choices.

A. Causes

6

7

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B. Effects

1

3

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to the next level.

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- 6 1. Austrailian biologists are raising tritons for future release as adults along the Great Barrier Reef.
- 7 2. Marine Biologists in Guam and Rota weekly study the coral reefs adjacent to new yacht harbor channels.
- 9 3. Scientists in Tonga, an island which has not been affected by the crown-of-thorns outbreak, are studying the ecology of coral reefs.

Directions: Again, compare your answers with those of your group. Where there are differences, try to resolve them.

Starfish Threaten

ONCE they head down the windward side of the island, we'll lose them," the marine scientist shouted over the outboard's roar. "It's too rough out there for small boats."

Sounds like a sheriff leading his posse after a gang of outlaws, I thought, as we knifed along the northern coast of Guam. True, our quarry was "speeding" at only a few hundred feet a day, but otherwise the analogy fitted. For, in their way, the marauders we had come to kill were as dangerous as any human desperadoes. They were spine-covered, coral-killing starfish, and they were destroying the living reef that shelters Guam's coastline from the continual pounding of the sea.

Rare nocturnal predators only a decade ago, these spiny multipedes have undergone a mysterious population explosion and now, by day as well as by night, menace coral reefs in widely scattered areas of the Pacific.

Casualty List Spans Half an Ocean

The prickly starfish, known commonly as the crown-of-thorns and scientifically as *Acanthaster planci*, eats the tiny coral polyps that create such reefs (page 348). In a single day it can graze an area twice the size of its 6- to 12-inch central disk.

Acanthaster has killed more than 90 percent of the coral along 24 miles of Guam's 100-mile coastline in two and a half years. It has also invaded 300 miles of Australia's 1,250-mile-long Great Barrier Reef, the world's most extensive example of the creation of reefs and islands by the flowerlike little polyps. The list of other coral areas under

Spearing coral-killing marauders, a Truk Islander impales two crown-of-thorns starfish. The mysterious increase of the species threatens destruction of Pacific reefs that harbor fish life and protect islands against eroding waves. Because a starfish cut in two may become two starfish, the pests must either be poisoned (pages 342-3) or be speared, as here, and brought ashore for burial.



ARTICLE AND PHOTOGRAPHS BY JAMES A. SUGAR

Pacific Reefs



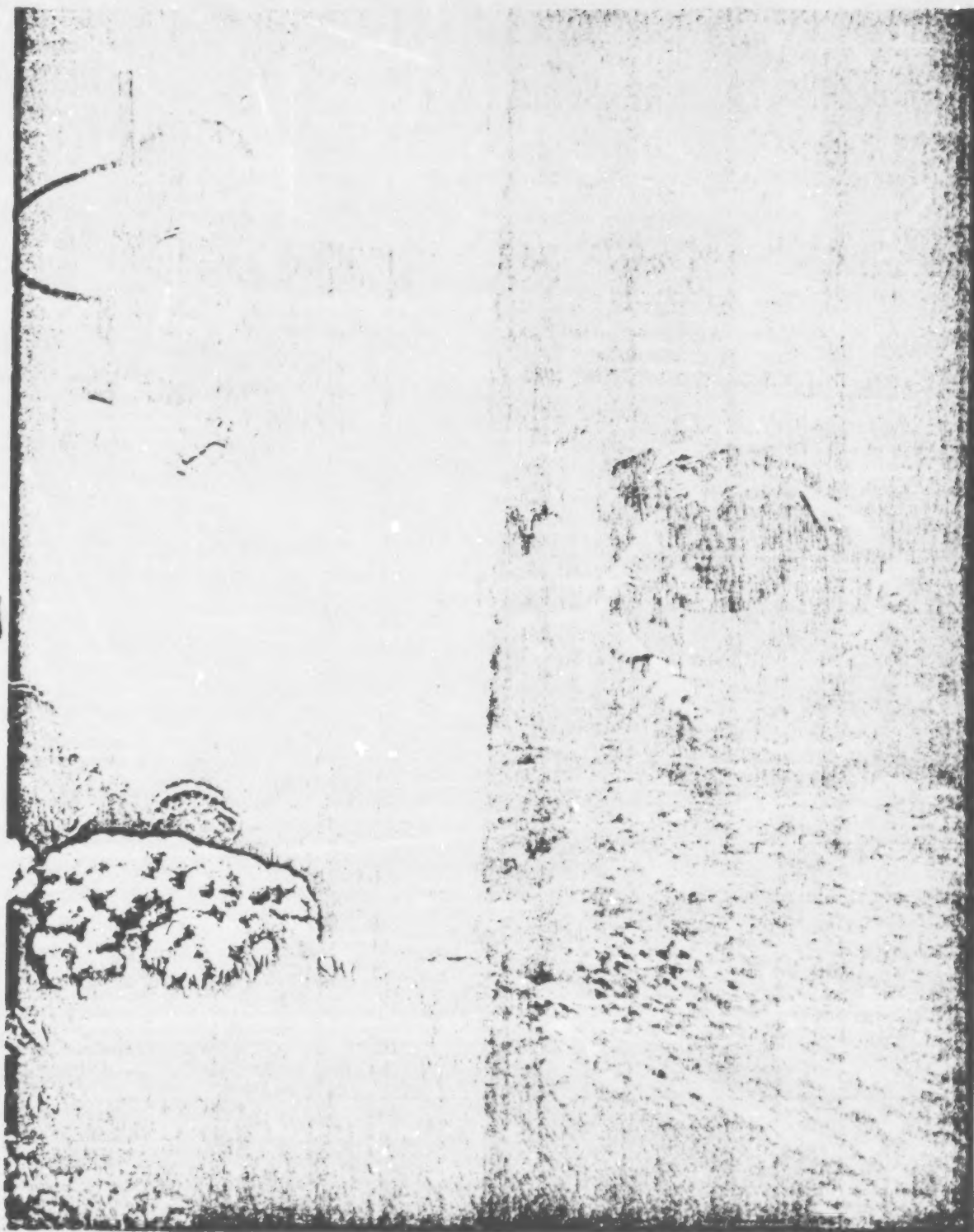
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Hypodermic guns go into action off Guan, where herds of starfish have left bleached coral skeletons, center. Stripped of living polyps, the reefs lie prey to small sea animals that bore into and weaken these natural barriers against the sea's erosive action. Hands gloved against thorns that



can poison, a diver with a hose-fed syringe injects a starfish with a lethal dose of formaldehyde solution (left). A team of four can kill as many as 2,500 in four hours. A rare nocturnal creature until it began reaching plague numbers seven years ago, the crown-of-thorns now feeds at all hours.

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assault by starfish has doubled and trebled: Malaysia, New Guinea, Palau, Saipan, Truk, Fiji, Tahiti, the Tuamotus (maps, opposite).

At last our scientist skipper, Dr. Richard H. Chesher of the University of Guam (right), shut down the engines. "The starfish have killed most of the coral back to Piti Bay," he said. "They're now moving at more than 2,000 feet a week, looking for live reef."

We strapped on scuba gear and started down. Each of us carried a special hypodermic syringe with which to inject a fatal dose of formaldehyde solution into our prey.

I soon spotted the sea stars sixty feet below me. Their dark multi-armed bodies stood out clearly against the pale sea floor. I could see scores of them traveling in a herd about ten yards wide and perhaps a hundred yards long. Their orderly formation reminded me of a parade moving to the cadence of a band. But I was sure that these starfish marched only to the beat of their own private drum.

I dropped down for a close look at one and was again reminded of the aptness of the name "crown-of-thorns." Dozens of sharp spines jut out from each of the animal's arms (below), as well as from the central disk. Besides simple pricking power, these thorns can



Menace on the march, a crown-of-thorns attacks a live coral head. Dozens of yellow-tipped feet flanked by blunt spines line the undersides of *Acanthaster planci*'s 12 to 19 arms. Most often it has 16, each of which may grow as long as six inches.

Suction cups on the ends of the feet carry feeding starfish up vertical reef walls. The predators, moving in narrow, irregular columns parallel to the shoreline, may migrate nearly half a mile a week.

poison; injuries from them sometimes cause swelling, pain, and even nausea.

I drew my knife and flipped a two-foot-wide creature onto its back. Its underside was covered with tiny yellow tube feet which enabled it to move in any direction (page 350).

Those tube feet, I soon discovered, function like suction cups. I lifted the star with my knife and tried to balance it on my underwater camera. It immediately wrapped its arms around the camera, enveloping everything but the strap. I used that to tow my living pincushion to the boat, where I had to use my knife again to break the grip of its arms and tube feet on the camera.

Spears Are the Answer on Small Atolls

Diver Mick Church bobbed to the surface. His air tank was empty, but he was full of predatory pride. He had killed 150 starfish with his formaldehyde gun.

"Man, I've never seen so many in one place before," Mick gasped as he tried to catch his breath. "They were all over the place, moving as if they were playing follow-the-leader. It looked like a scene from a science-fiction movie—an invasion from inner space."

"We can control the invasion here in Guam," said Dr. Chesher as we stowed our gear. "Not long ago our killer team destroyed 2,549 starfish in four hours. The trouble is, people on most of the outlying islands don't have all this equipment. We'll have to teach them to collect the starfish on spears [pages 340-41] and bury them on land. Just stabbing them isn't enough. A pierced star may not die. If you chop one in two, both halves may regenerate and become complete individuals."

Driving home from the dock, Dr. Chesher told me that people living on low-lying Pacific islands face real danger as a result of the starfish's depredations.

"When live coral is killed, reefs may break down," he said. "Then storm waves might eventually eat away shorelines. But before this could happen, islanders might be forced to leave or starve. They get almost all their protein from the sea. Once the reefs die, food fish go too."

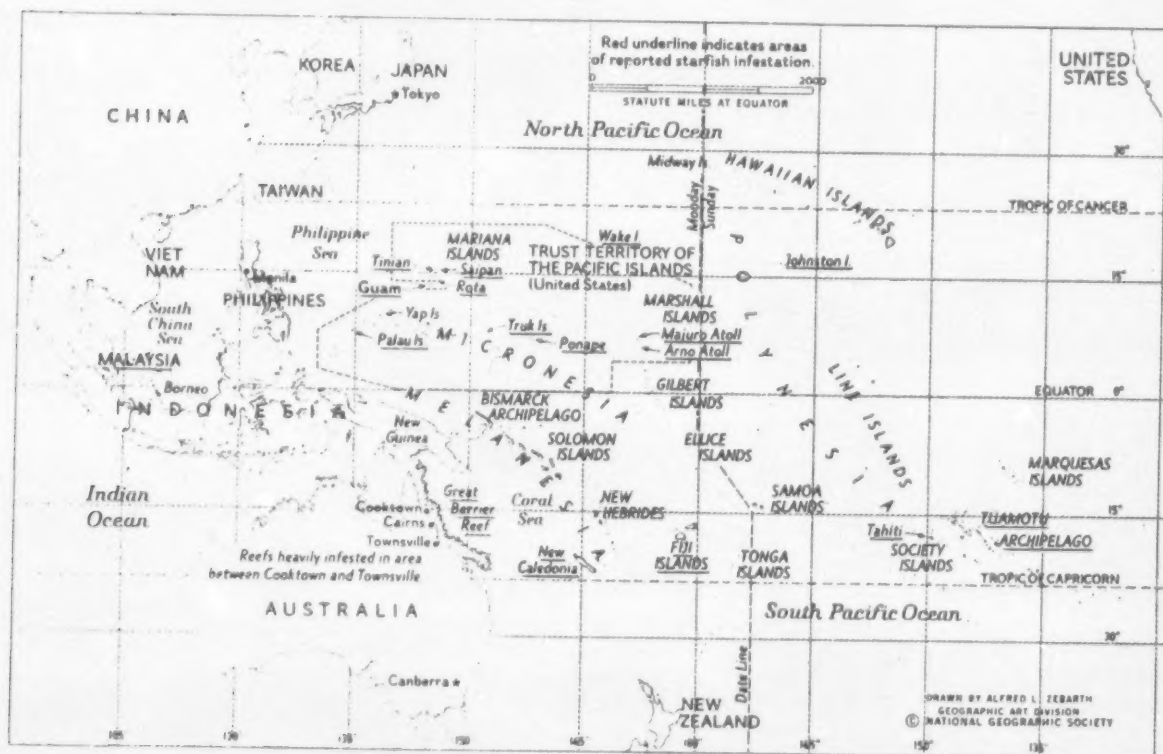
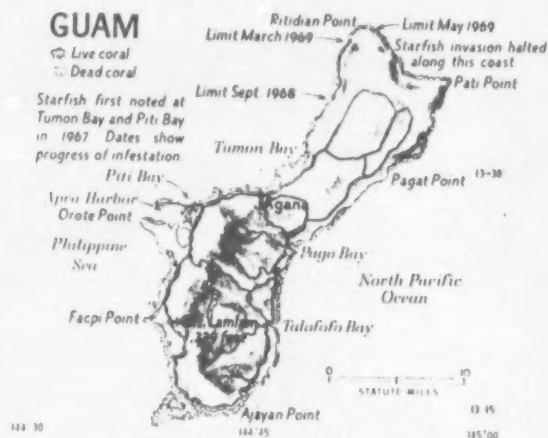
The possibility that such a disaster might strike the Pacific Islands Trust Territory, administered by the United States, prompted the U. S. Department of the Interior to send out an international team of more than 60 scientists and divers to study the problem last summer. The project, managed by the Westinghouse Ocean Research Laboratory of

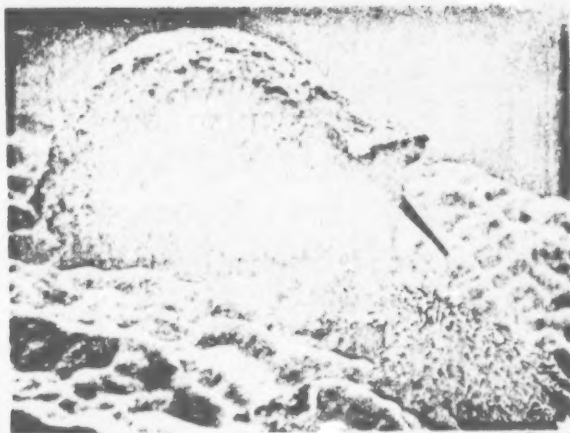


Gearing up for a look at the invader, Dr. Richard H. Chesher adjusts air tanks. Chief scientist of an intensive United States Department of the Interior study, he seeks causes and effects of starfish proliferation.

Crown-of-thorns depredation was first reported a decade ago on Australia's 1,250-mile Great Barrier Reef (bottom), world's most awesome coral formation. Starfish were ravaging reef areas between Cooktown and Townsville in Queensland. Plague reports multiplied, reading like a Pacific war map of the 1940's: Malaysia, Borneo, Guam, Saipan, Tinian, Truk.

Starfish-killer teams armed with formaldehyde syringes think they have contained the plague on Guam (below). But *Acanthaster's* appetite threatens many small atolls, where scientists hope to teach islanders simpler extermination methods (pages 340-41).





STACHROMES BY JAMES A. SUGAR (C.N.S.)

Triton's searching tentacles set off a low-speed chase

PROBING FOR A MEAL which the author placed nearby, a Pacific triton (above) sends a crown-of-thorns fleeing over a coral head at 12 inches a minute. The race ends with the starfish locked between the attacker's foot and its algae-flecked shell (right).

Its prey immobilized, this triton rolls over, flipping the starfish on its back (opposite, below). Then the mollusk tears it to shreds with its filelike radula and digests it. Sometimes a half-eaten starfish skitters away at mid-meal, eventually its amputated portions may regenerate. Some scientists blame *Acanthaster*'s increase on collectors who pay \$35 or more for spiraled triton shells. Australia hopes to raise the giant mollusks for release on starfish-infested reefs.



San Diego, California, was set up to survey the damage caused by *Acanthaster*.

But the team also studied the animal's behavior, particularly its eating habits. Dr. Ralph W. Brauer, of the Wrightsville Marine Bio-Medical Laboratory in North Carolina, collected starfish which he kept in aquariums at the University of Guam, where he could observe them closely (page 350).

I accompanied Dr. Brauer and his two colleagues, David Barnes and Mike Jordan, on a collecting expedition to an infested reef along Guam's western coast. In an outboard-propelled rubber raft, loaded with diving equipment and large buckets for holding the starfish, we rode to a spot where I had seen starfish feeding a few days earlier. We located a cluster of the creatures, dropped anchor, and put on our gear.

"Be careful when you handle these critters."

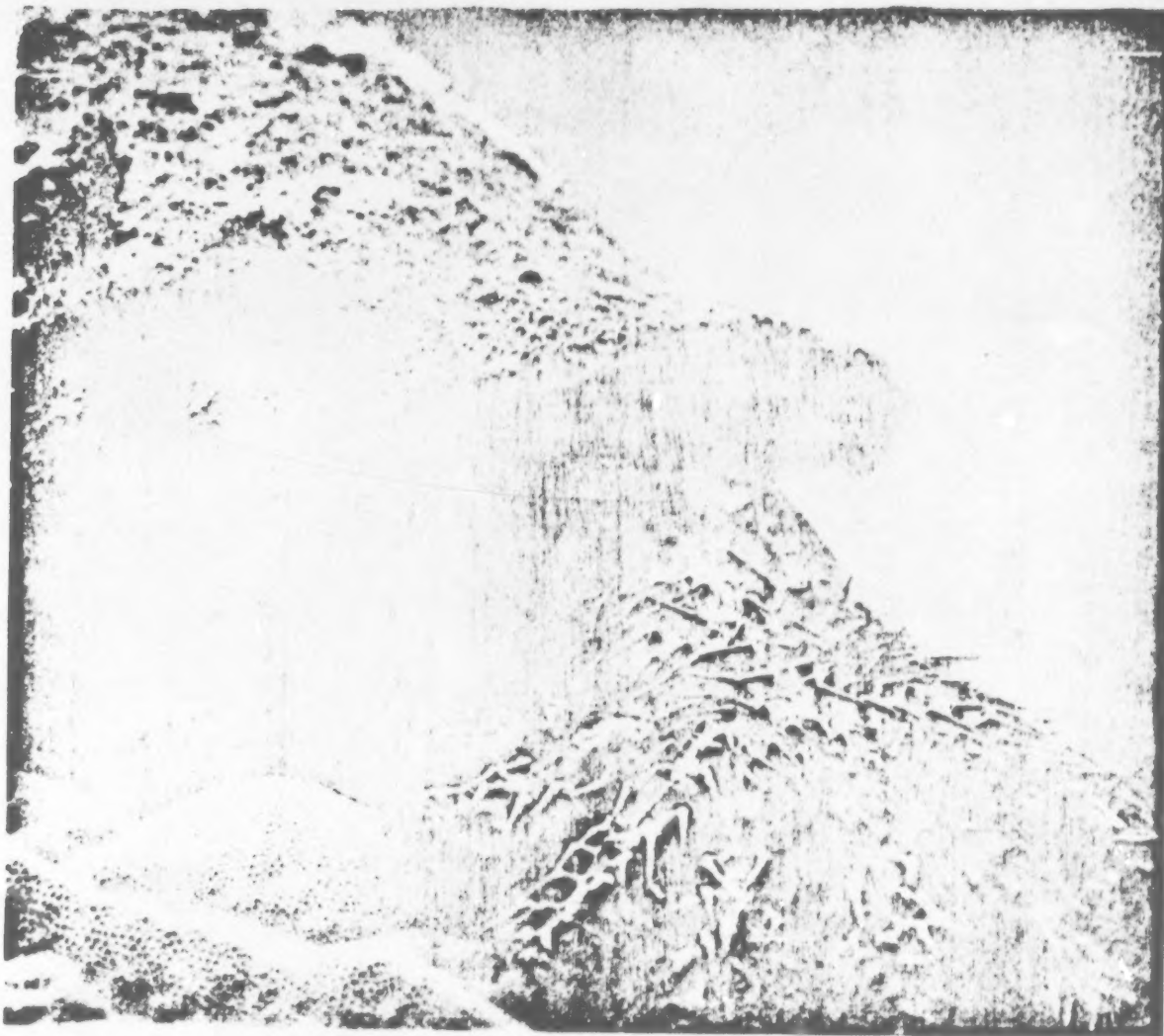
Dr. Brauer warned us. "I don't want you to damage the animals or yourselves. Watch out for their spines!"

We headed for the bottom. Here the sea floor was covered with coral heads of all shapes and sizes. Only a few *Acanthaster* were feeding on top of the heads. Most of them were well hidden under the coral, to which they held firmly with their arms and tube feet. To remove the starfish, I used my knife with the care of a surgeon, heeding Dr. Brauer's warning as I worked.

Spines Can Cause Painful Wounds

The four of us shuttled back and forth between the raft and the coral heads on the bottom. On each trip up we brought one starfish to the surface, put it in a bucket on the raft, and headed back down for another.

On Mike's last trip to the surface, he handed



a starfish to David, who was in the raft. A spine brushed David's finger. Light as the touch was, it gashed his skin.

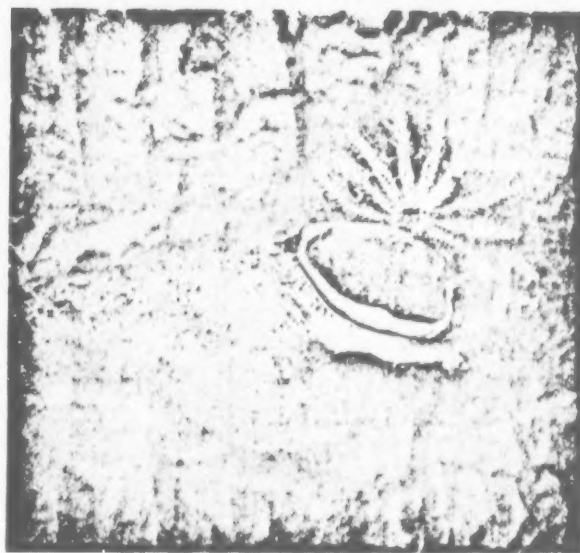
David yelped.

"Force the cut to bleed," Dr. Brauer told him. "Get the stuff out of the wound. If you do it right away, you'll have less pain later."

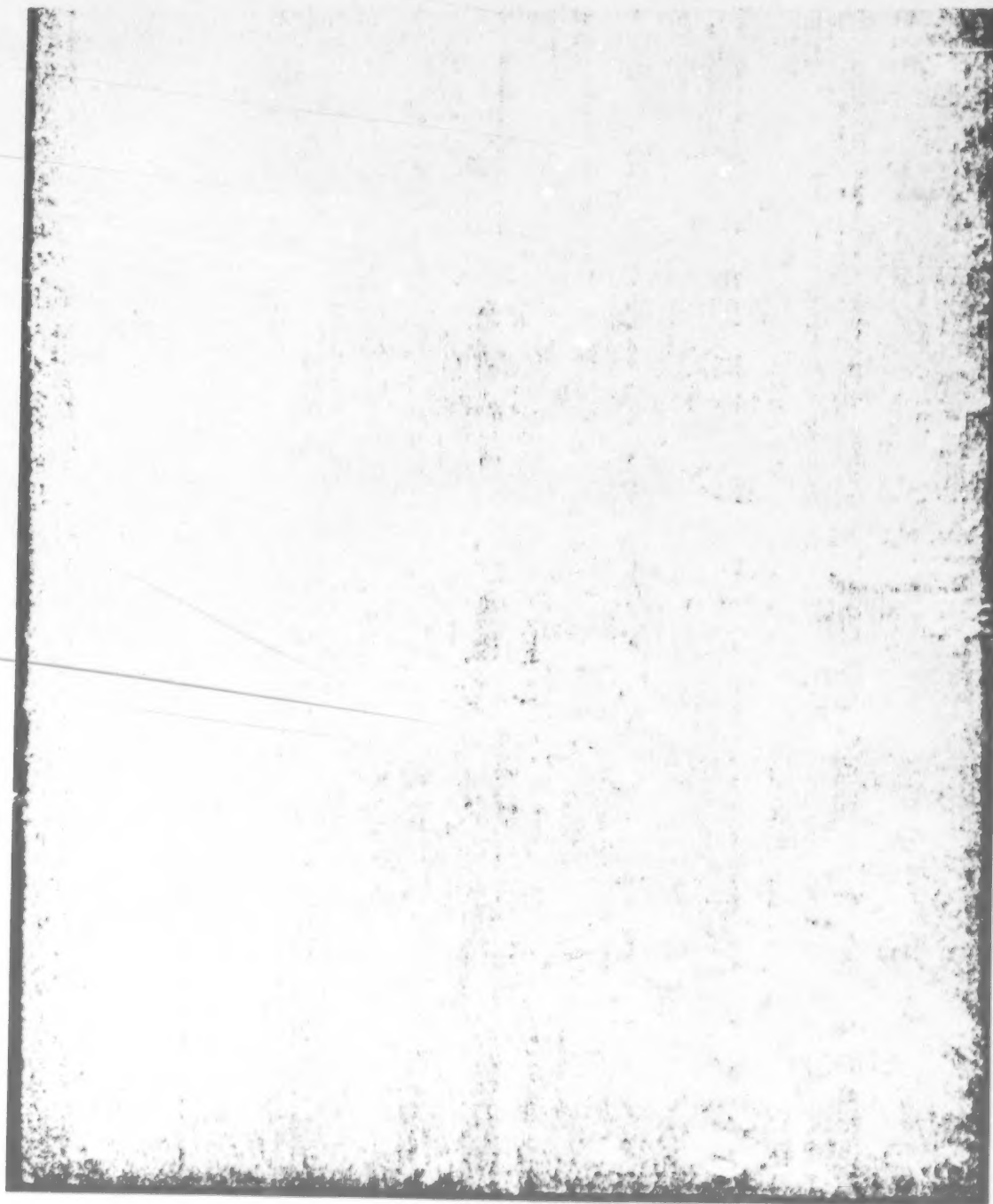
When we released our starfish in glass-walled tanks at the university, Dr. Brauer ran sea water over some living coral, filled a hypodermic syringe with the polyp-flavored water, and squirted it under a starfish creeping up the glass wall.

Mistaking the coral taste for live coral, the starfish opened its mouth (located in the center of its underside) and everted its stomach. The fleshy digestive sac covered an area larger than a man's palm (pages 350-51).

Next Dr. Brauer placed a hungry starfish on a piece of living coral. Out came the

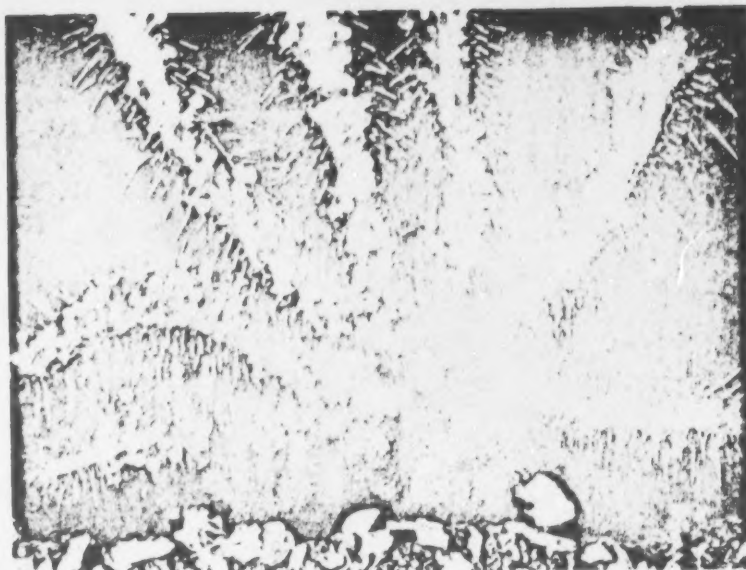






STEREOPHOTO (ABOVE) BY JAMES A. SUSAN. ANACHROME BY PAUL J. TZIMOUKIS. C. N. S.

The quick and the dead: Flowerlike coral polyps (left), enlarged $7\frac{1}{2}$ times, were long mistaken for plants. Simple, stationary animals, they attach themselves to the skeletons of their ancestors and exude calcium carbonate to build a home around themselves. Withdrawn into their limey cups by day, polyps unfold tentacles at night to feed on microscopic sea life. In one of nature's strangest vendettas, they devour millions of starfish in the larval stage. Thus man's destruction of coral reefs by blasting and dredging channels may contribute to the growth in starfish population. Desolation invades oceanic gardens of Guam (above) in *Acanthaster's* wake. Thick fuzz of algae quickly covers dead coral, preventing new growth.



A stomach goes out to lunch

WHIELDING A SYRINGE, Dr. Ralph Brauer squirts coral-flavored sea water along the underside of a captive starfish at the University of Guam (above). The stimulated *Acanthaster* hungrily opens its mouth in an experiment that demonstrates the creature's feeding behavior.

Live polyps placed on the tank bottom attract the predator (above right). It moves its tube feet excitedly and begins to evert its gastric sac, a billowy membrane which, when fully extended, covers an area larger than its central disk. "It tumbled around the coral like a collapsed parachute," observed author Sugar.

As the membrane enlarged three times at right—drapes over the polyps, digestive juices pour from the body to dissolve the food into semifluid strands of tissue. The starfish then absorbs its meal, though scientists do not yet know exactly how. Within eight hours all coral covered by the stomach area will shine bone white—shorn of life.



stomach. It spread over the coral polyps, and its digestive juices began to dissolve them inside their limey shelters. After an hour, the polyps were reduced to semifluid shreds. Where colonies of colorful little animals had lived, there remained only a bleached white skeleton.

"In a single night," Dr. Brauer told me, "an adult starfish can clear off a coral head that might have taken fifty years to grow."

Giant Tritons Prey on Stars

While such studies of the sea star's habits may lead eventually to a means of controlling the present plague, some scientists are seeking more immediate solutions. Australian biologists, concerned about the threat to the Great Barrier Reef, plan to attack the stars with armies of their natural enemies, giant tritons. They believe that man has upset the delicate ecological balance of the reef by collecting too

many of these mollusks for their handsome spiral shells, permitting the stars to multiply abnormally.

"I have calculated that shell collectors took at least 100,000 tritons from the Great Barrier Reef between 1949 and 1959," says Dr. Robert Endean of the University of Queensland. "We are trying to find out whether it's possible to grow these animals on a special triton farm. If it is, we'll seed them as adults along the Great Barrier Reef."

Having once watched a giant triton devour an *Acanthaster*, I can vouch for its voraciousness. The triton first located the star with its two tentacles. The threatened starfish tried to creep away, but its pursuer chased it across a coral head and caught it. The mollusk first seized the starfish, holding it between shell and foot, then began to tear it to shreds and eat it (pages 346-7). Several hours later, it ejected the spines.

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ENTACHROMES BY JAMES A. SUGAR © NATIONAL GEOGRAPHIC SOCIETY

If isolated or somehow contained within a given coral area, the crown-of-thorns soon curbs its own population explosion—at the cost of a totally dead reef. "*Acanthaster* become so numerous they eat themselves out of house and home," explained Richard Randall, an expert on the corals of the Marianas.

While I browsed through the dozens of coral-laden racks in his house on Guam, Mr. Randall pointed out that the devastation of a reef leads to starvation of the starfish—though only after it has led to the starvation of other reef creatures, and perhaps humans as well.

Man May Have Set Off the Plague

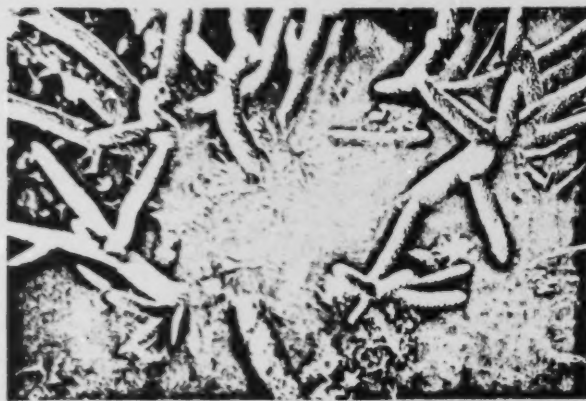
Can a reef recover from a starfish attack? Mr. Randall is trying to find out.

Coral regeneration is difficult because the porous skeleton of a ruined reef is soon covered

Chesher told me that man may be responsible in another way for the invasion. "By killing coral in the process of blasting channels or dynamiting for fish," Dr. Chesher said, "he has perhaps altered the underwater environment in favor of the sea-star's survival."

Dr. Chesher explained that under normal conditions only a tiny percentage of the millions of eggs spawned by the female *Acanthaster* ever reach adulthood. Many of the floating starfish larvae are devoured by living coral polyps. But when an area of reef is killed by man, the vulnerable larvae can settle upon it and mature in safety.

Because there is usually living coral immediately adjacent to the dead reef, the young adults have a ready food source once they begin to eat polyps. As the adult starfish destroy even more of the reef, they enlarge the



Deadly embrace dooms a prong of staghorn coral. Nearby, a whitened branch stands stripped of polyps like an ear of corn denuded of its kernels. Among the reef-building corals, few varieties enjoy immunity from the starfish.

Paradise in peril: Plagues seem far from mind as two islanders at Guam fish with dip net and bucket through a serene dusk. But scientists fear their way of life may vanish if the crown-of-thorns goes unchecked and the underwater ecology continues to change.

with algae which prevent new growth. Within two or three days the white skeleton becomes a dismal gray, coated with fuzz (page 349) or festooned with long green strands.

No single theory offered to date has adequately explained the starfish plague and its wide distribution. Some scientists speculate that the population explosion has no unusual cause but is only a natural periodic phenomenon. Other theories seem valid for certain areas but not for others. Many Australian scientists are convinced that over-collection of giant tritons created the plague on the Great Barrier Reef. But lack of intensive shell collecting in remote island areas, now equally star-infested, indicates other causes as well as triton harvesting.

In his office at the University of Guam, Dr.

sanctuary for their young. The result of the chain reaction is a population explosion.

"Support for my hypothesis," Dr. Chesher pointed out, "comes from the fact that infestations in Guam, Rota, and Ponape were first discovered near blasting or dredging sites."

Others have wondered whether the imbalance in reef life might have been caused by the testing of nuclear weapons, or by pesticide residues washed into the oceans from the land. Whatever the cause may prove to be, all the theories advanced so far—except that of natural periodic population growth—point to the activities of man. Whether by dredging, or shell collecting, or pollution, this latest disturbance of the balance of nature seems to be a further example of man's disruption of his world.

THE END

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TEACHER BACKGROUND - Urchins

Sea urchins are abundant in many areas off the coasts of the United States and Canada. While these highly armored creatures may seem to bear only slight resemblance to sea stars and sea cucumbers, the presence of tube feet, radial symmetry and the five fold star-like arrangement of body parts clearly show the relationship that exists between these animals. Sea urchins are prized as edible in certain areas, most notably Japan, and on the west coast there is a small commercial fishery for urchins. Since eggs and milt are all that is eaten, sea urchins perhaps provide less to eat than any other edible animal. As an aside, attempts to reduce sea urchin populations in kelp beds have been tied to attempts to satisfy the Japanese demand for urchin gonads.

Because of the ease with which sea urchin eggs can be manipulated, the sea urchin has been used extensively by biologists studying animal development. As such, the fertilization and early development of sea urchin eggs have been two of the most carefully studied events in the life of any animal. The information gathered by these biologists provides the material for the laboratory activity which follows. This activity can be used as a springboard for discussions dealing with the seeming paradox between cell division and cell differentiation. Cells divide to form identical daughter cells, yet, organisms are not made of large masses of identical cells.

While this laboratory activity requires some special techniques, none of them is difficult. It is impossible to determine the sex of most sea urchins from their external appearance. Therefore you must obtain enough mature specimens to be reasonably sure of having at least one male and one female. The color of the gametes can be used to distinguish the sexes. The sperm are white; the eggs are red or orange.

Sea urchins are not "ripe" all year long. However, since different species are ripe at different times, there is no period during the year when mature individuals are unavailable. For example, the purple urchin (Strongylocentrotus purpuratus) is

mature from December to May while Lytechinus pictus is ripe from June to September.

If you are not able to collect your own sea urchins, sea urchin embryology kits may be obtained from the following sources:

Carolina Biological Supply Company
Powell Laboratories Division
Gladstone, Oregon 97027
phone (800) - 334 - 5551

Pacific Bio-Marine Supply Co.
P. O. Box 285
Venice, California 90293
phone (213) - 397 - 9702

Gametes may be obtained from mature adults by dissection. The obvious disadvantage to this technique is the demise of the urchin. Other techniques are available which permit the urchin to live again for another day of gamete production (they are actually ready to be reused after about three weeks). Electrical stimulation will cause gametes to be released. The procedure involves attaching wires to the electrodes of a 6-10 volt battery. The ends of the wires are touched to the shell of the urchin. Sperm or eggs will be exuded from small pores around the mouth. The gametes may be collected in a finger bowl or beaker.

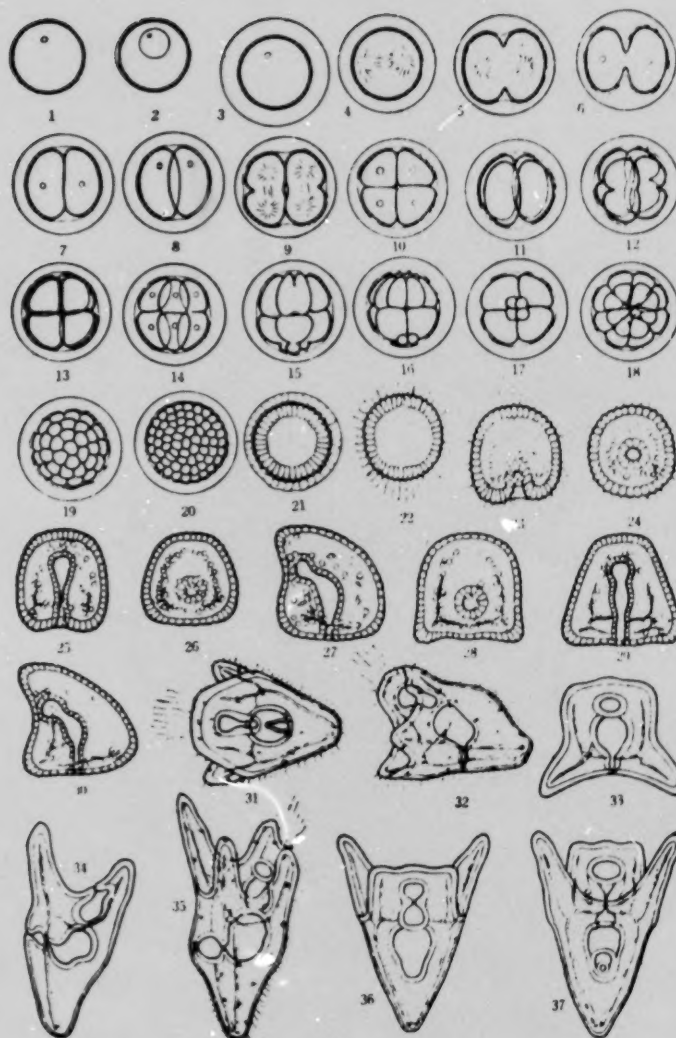
Perhaps the most widely used technique involves the injection of a 0.5M solution of potassium chloride into the body cavity. The sea urchin is placed upside down in a beaker filled with sea water. One to two milliliters of 0.5 M KCl solution is injected into the body cavity by inserting the full length of a syringe through the soft membrane surrounding the mouth. The needle should be of sufficient length to reach into the body cavity of the urchin. Large urchins may take up to 10 ml of solution. The urchin is placed, oral side down, on a clean surface. Ripe males will produce a milky white mass of sperm on the aboral side. Ripe females produce a cream to orange-red mass of eggs on the aboral side.

Stock egg suspensions may be prepared by filling a narrow 250 ml beaker or a finger bowl with filtered sea water. The female is inverted over the beaker to permit the eggs to drain into the water below.

The sperm is oriented by inverting a hole punch in a sterile petri dish so that the sperm falls on the dry surface. The covered sperm may be refrigerated and will remain viable for about 24 hours. Return the sea urchins to salt water.

Duplicate the laboratory activity pages. One set is recommended per student. Caution your students beforehand to use good lab techniques. To avoid contamination, be sure to label the pipettes used for withdrawing samples from the stock solution and the sperm container. If you fertilize eggs at various times in advance of the laboratory period, your students will be able to observe several different stages simultaneously. If room permits, have your students store their fertilized eggs in a refrigerator for observation of developing larvae at 24 and 48 hours. Sketches of different stages of development are shown below to aid you in identification. Student sketches make an interesting bulletin board display which can not only teach but inspire interest from diverse segments of the school population. Upon completion of the laboratory activities, provide time for a discussion of the procedure and to provide answers to the questions posed in the text. This is an interesting and informative experience for your students, capitalize on the discussion topics that will surface.

LARVAL DEVELOPMENT



The larval development of sea urchins in the family Strongylocentrotidae. Drawings 1-37 represent the larvae of *Hemicentrotus pulcherrimus* reared at temperatures of 10-15 C and are from Okada and Miyauchi (1954). (1) Unfertilized egg, diameter 80-90 μ; (2) mature egg; (3) fertilized egg; (4,5,6) first cleavage, 1.5-2.0 hours after fertilization; (7,8) views of two-cell stage, 2.0-2.5 hours; (9) second cell division; (10,11) views of four-cell stage, 3-4 hours; (12) third cell division; (13,14) views of eight-cell stage, 4-5 hours; (15) fourth cell division; (16,17) views of 16-cell stage, 5-6 hours; (18) 28-cell stage, 6-7 hours; (19) 64-cell stage, 9 hours; (20) early blastula, 160 cells, 14-16 hours; (21) blastula at 20 hours; (22) blastula with cilia at 23 hours; (23) gastrula at 32 hours; (24) at 42 hours; (25,26) views of late gastrula at 52 hours; (27,28) prism larva at 64 hours; (29,30) prism larva at 76 hours; (31,32) pluteus at 86 hours, length 200 μ; (33,34) at 100 hours, 270 μ; (35,36,37) pluteus at 120 hours, length 300 μ; (38) eight-arm pluteus of *Strongylocentrotus purpuratus* from Strathmann (1971); (39) aboral view of *S. intermedius* larvae during metamorphosis, 926 μ, from Kawamura (1973).

From: Mottet, Madelon Green. 1976. The Fishery Biology of Sea Urchins in the Family Strongylocentrotidae. State of Washington Department of Fisheries Technical Report No. 20. 66 pages.

KEY

Part I

- 1, 2, 3, 4a. Answer depends upon the experimental observations.
- 4b. The teeth are used to scrape off and crunch up encrusting growths like barnacles, hydroids, tube worms, sponges, and algae.
- 5a. Answer depends upon the experimental observations.
- b. Possible benefits from sea urchin burrowing behavior include: protection from predators; protection from wave action; and protection from drying during the low tide since the cavity holds water. Your students will probably devise other possible benefits.
- 6a. Podia may help sea urchins survive by:
 - attaching the urchin firmly to the bottom so that they may avoid predators, wave action, etc.;
 - aiding in locomotion;
 - securing small food items; and
 - moving items to or from the mouth.
 Your students will have other suggestions.
- 7a. Three opposing "teeth" form the jaws on the pedicellariae.
- b. The food captured by the pedicellariae may be transported from one pincher to the next, down to the mouth where it can be eaten. The pedicellariae are also used to keep the surface of the shell clean or, conversely, they may hold objects onto the surface of the test for either camouflage or shade.
8. Answer depends upon the experimental observations.

Part II

- A. To maintain a constant population size only two of the sea urchin eggs laid and fertilized during the life of the sea urchin must reach maturity.
- B. The answer to A above coupled with the number of eggs laid would seem to indicate that the odds of any given fertilized egg reaching maturity must be very small.
- 1., 2a. Answer depends upon experimental observations.

Analysis and Interpretation

1. There are several reasons sea urchin eggs are used in embryological studies. The principal reason relates to the ease with which they may be obtained and fertilized. Sea urchins are also intertidal residents, an area that often suffers more severely from man's actions. You may wish to discuss the merits of studying possible deleterious effects only on "convenient" or "easy" animals like the sea urchin. The potential exists for selective effects from pollutants; the sea urchin may not be affected while other organisms around it suffer.
2. Since external fertilization is used by successful groups of animals it must be a successful adaptation. Similarly the case can be made that internal fertilization is successful. In addition, one must look at the difference between internal development and external development after internal fertilization. The disadvantages to external fertilization seem most obvious: large numbers of eggs and sperm must be produced to ensure fertilization; sperm and egg cells may be prevented from meeting by sudden currents or similar environmental changes, etc.; the gametes are subjected to the uncontrollable environmental effects of water temperature, salinity etc. The advantages seem to fall to the individual; once the gametes are released, their obligation is over. This question can provide for discussion of the idea that there are many ways an organism can successfully accomplish life.
3. The primary advantage to the drifting phase of development is that the drifting larvae are carried into new areas thereby extending the range of the sea urchin.

The answers will vary. Since the question asks for an opinion there is no "right" answer. The question is designed to provide an opportunity to discuss the danger of labeling one species as "good" and another as "bad". It is important to remember that these organisms have coexisted for millions of years and that each, in some way, benefits from the actions of the other. With our present state of knowledge, we are in no position to make arbitrary decisions about the worth of other species.

KEY WORDS

aboral

Aristotle's Lantern

blastula

development

Echinodermata

eggs
external fertilization
fertilization
flagellum
gametes
gastrula
kelp
mortality
nucleus
oral
pedicellariae
pelagic
pipettes
pluteus
podia
predation
radial symmetry
range
sea urchins
sperm
suspension
water vascular system
yolk granules

URCHINS



No animal fills the bill of "spiny-skinned" better than the sea urchin. Sea urchins have been used for food since at least the days of ancient Greece. Even today, sea urchin eggs are considered a delicacy in many parts of the world. Ancient Romans used sea urchins as medicine. The urchin, spines and all, was ground, mixed with a cup of wine or vinegar, and quaffed. In some cases, urchins were burned with snake skins and frogs, the ashes were mixed with vinegar. One cup a day was drunk to improve the eyesight. In the following exercise, the bitter cup you will have to drink involves the examination of the external anatomy of the sea urchin and an introduction to the fertilization and development of the sea urchin egg.

Materials:

live sea urchins (Strongylocentrotus purpuratus - ripe
December to May)
(Lytechinus pictus - ripe June to
September)

sea water

filtered sea water

finger bowl

dissecting microscope

250 ml flask

10 ml pipette

sea urchin egg suspension
sea urchin sperm suspension
compound microscope

Procedure:

Part I - External Anatomy

1. Obtain a living sea urchin and place it in a finger bowl of sea water.
 - a. What color is your sea urchin? _____
2. Measure the diameter of your sea urchin and RECORD the diameter in centimeters. _____ cm.
3. The sea urchin body can be divided into oral (mouth) and aboral (away from the mouth) hemispheres which display the radial symmetry typical of the Echinodermata. Observe the aboral surface of the live specimen.
 - a. Are the spines of equal length? _____
 - b. Are the spines in one region longer than the spines of another region? _____
If so, where are they the longest? _____

4. Observe the oral surface of the live sea urchin. The mouth of the sea urchin is surrounded by a toothed structure called Aristotle's Lantern. The tips of the teeth are just visible through the open mouth. The sea urchin uses these teeth to scrape off and crunch up encrusting growths like barnacles, hydroids, tube worms, sponges and algae. These teeth wear away with constant use. The worn area is replaced from above by the downward shifting of the entire tooth

as it grows at the upper end.

- a. How many teeth (points) make up Aristotle's Lantern? _____
- b. How do these teeth aid the sea urchin in feeding?

5. Gently touch the spines.

- a. Describe their movement _____

The purple urchin, Strongylocentrotus purpuratus, of the Pacific coast burrows into rocks. These urchins use a combination of spine rotation and chewing to wear away the rocks on which they live. Eventually, they excavate a cup shaped depression into the rock.

- b. What is one possible benefit of this burrowing behavior? _____

6. Observe the tube feet or podia. The podia are long, tube shaped structures, with a flattened tip forming a sucker. Podia are part of the water vascular system. When the podia come into contact with a hard surface, the center of the terminal sucker is withdrawn producing a vacuum and adhesion.

- a. What are two ways in which the podia might help the sea urchin survive?

1. _____

2. _____

7. Observe your specimen with the aid of a dissecting microscope. Structures known as pedicellariae are found between the spines. Each pedicellaria bears a jaw-like apparatus used for protection and to capture small animals. In some sea urchins the pedicellariae contain poison glands.
- a. How many opposing "teeth" form the jaws? _____
- b. How might the food captured by the pedicellariae be transported to the mouth? _____
8. Gently turn over your sea urchin. (If possible, place the sea urchin on a sandy substrate.) Describe the action of the spines and tube feet as the animal rights itself. _____

Part II - Reproduction and Development

Sea urchins normally discharge gametes (eggs and sperm) into the sea where fertilization occurs. This process, external fertilization, is very common among aquatic organisms. With luck, the fertilized eggs develop into free floating, pelagic (open sea) larvae. These larvae provide for the distribution of sea urchin species and are responsible for extending the range (area in which the urchin species is found) of the species. There are great risks inherent in this free-floating lifestyle.

Many larvae may be carried to locations where the substrate is unsuitable for sea urchin growth. Many more larvae are eaten by larger animals. To compensate for these high mortality rates, millions of eggs are shed by each female and even more sperm is shed by each male.

- A. To maintain a constant population size how many sea urchin eggs must reach maturity to replace each pair of sea urchins? _____

- B. Are the odds very good that any given fertilized egg will reach maturity? _____

Procedure:

1. Obtain a drop of unfertilized sea urchin egg suspension. (Your teacher will provide the suspensions or instructions regarding how to obtain them). Place the drop on a depression slide, cover and observe using a compound microscope. The eggs are spherical and surrounded by a jelly coat. Mature eggs will show a small clear nucleus and uniformly distributed pale yolk granules.
 - a. In the space below, sketch an unfertilized egg.
Label the nucleus and jelly coat if visible.

2. Obtain a drop of sperm suspension and place it on a depression slide. Cover with a coverslip and observe using a compound microscope. The sperm swims by agitating its whip-like flagellum. You may be able to see the flagellum if you decrease the amount of light transmitted through your microscope.
 - a. In the space below sketch a sperm cell. Label the nucleus and flagellum if visible.

b. How does the size of the sperm cell compare with that of the egg cell? _____

3. Using separate pipette (Caution: do not mix the pipettes) add one drop of the sperm suspension to one ml of the egg suspension in a 250 ml flask filled with filtered sea water. Mix well by swirling.

RECORD the time.

Time (_____)

4. Pipette a drop of the egg-sperm mixture onto a depression slide. Seal a coverslip over the mixture using petroleum jelly (Vaseline) around the edges of the coverslip. Immediately examine the eggs under a microscope using low power (10x). After locating eggs, switch to high power. Under the high power, sperm will be seen clustering around the egg. Sperm

penetration can be seen very soon after the eggs and sperm are mixed. Normally, only one sperm cell will penetrate the egg. A fertilization membrane will form over the egg.

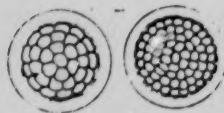
- a. RECORD the time at which the membrane first appears.

- b. How long a time elapsed between the mixing of the gametes and the formation of the fertilization membrane? _____

- c. In the space below, sketch the fertilized egg.
Label the fertilization membrane.

5. By placing the suspension in a refrigerator, you may save your fertilized egg-sperm suspension for observation of more advanced stages of development tomorrow and the following day.
6. Observe and sketch eggs fertilized earlier in the day by other classes or by your teacher. Label each sketch to show the number of cells present.

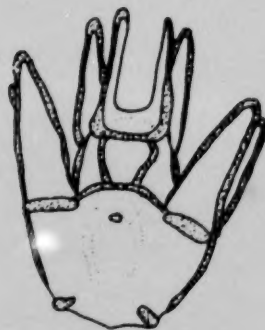
7. The next day and the day following that observe and sketch your fertilized egg. By about 10 hours following fertilization, the fertilized egg has become a hollow ball of cells called the blastula. The blastula becomes flagellated and free-swimming within twelve hours.



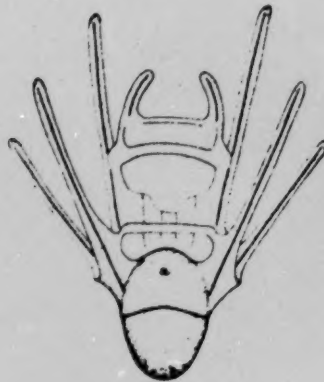
At about 32 hours the blastula becomes folded in upon itself to become the gastrula.



The gastrula undergoes continued cell division to become the planktonic, feeding pluteus larvae at about two days.



Development from the pluteus stage to the adult may take several months. The young urchin now about 1 mm in diameter, sinks to the bottom as the skeleton forms and assumes the lifestyle of the adult.



SKETCHES

24 hours

48 hours

8. Place the sea urchin larvae in the container provided by your teacher and clean the glassware and equipment you have used.

Analysis and Interpretation

1. What is one possible reason scientists have used sea urchin eggs to study the effects of pollutants on embryological development?
2. What is one advantage of external fertilization? What is one disadvantage of external fertilization?
3. Developing sea urchin larvae are highly susceptible to predation. Lots of animals would like to eat them. It would seem advantageous for them to hide, rather than to drift in open water. What is a primary advantage to the drifting phase of development?
4. Kelp harvesters view sea urchins as a threat to the kept beds. Some harvesters would like to eliminate the sea urchin. In view of the fact that the kelp beds and the sea urchin have coexisted for thousands of years, how would you reply to these harvesters?

BIOLOGICAL FACTORS:

Animals With Backbones - Phylum Chordata

503

TEACHER BACKGROUND - The Chordate Connection and A Lot of Nerve

The Phylum Chordata incorporates about 46,000 diverse species. Chordates are found in almost every habitat in marine, freshwater and terrestrial systems. Within the diversity, taxonomists recognize several common characteristics:

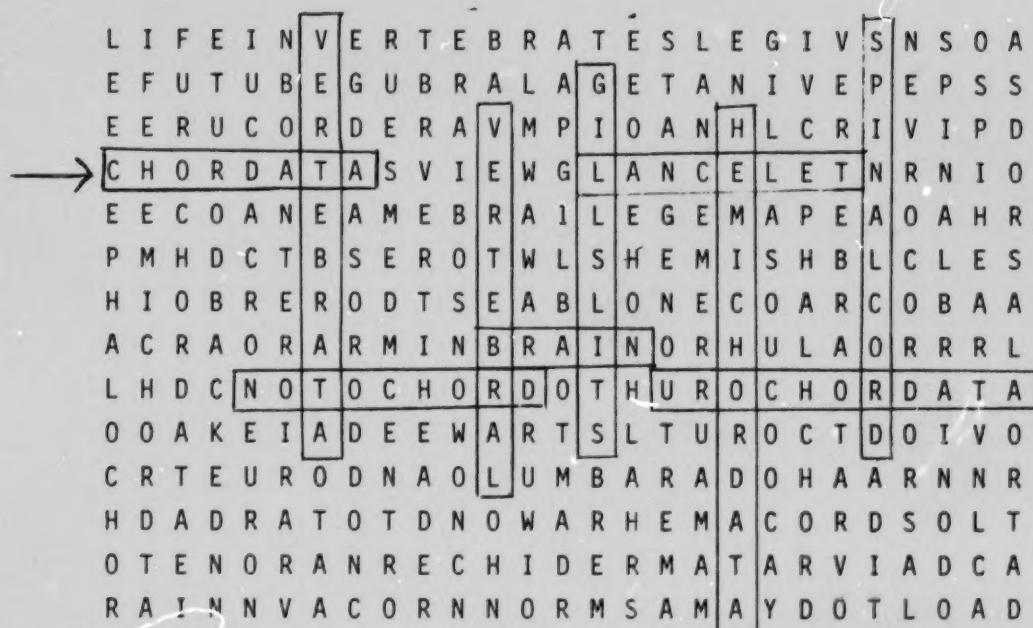
- bilateral symmetry
- hollow dorsal nerve tube or cord and a stiff notochord (part of the skeletal system) beneath it (may be lost or replaced during development)
- several pairs of pharyngeal pouches in the "throat" region (these become perforated to form gill slits)

The chordates include the marine animals with which your class will be most familiar. Familiarity has its advantages and its disadvantages. While you will have some common ground from which to work, you will need to choose examples that will spark the interest of your students. The urochordates, hemichordates and cephalochordates, including the much studied Amphioxus, are treated only in passing in this section. Selected vertebrates will be studied in more depth in activities which follow. The following sections will begin to expand the discussion of man's current and future roles in the sea.

"A Lot of Nerve" is designed to reinforce the new vocabulary. Since your students may not be familiar with this type of modified crossword/word search, you may need to review the instructions before they proceed. This activity underscores the fact that the vocabulary load in science is heavy and makes reading science difficult for most students. You can help reduce this barrier to comprehension by incorporating the new vocabulary into your discussions of the materials covered.

Duplicate the text and activity pages. One set is recommended per student. This activity is best accomplished by individual students. You may wish to have students meet in small groups to discuss their answers to "A Lot of Nerve" before you provide the correct answers. Alternatively, you may elect to have small groups complete "A Lot of Nerve". Select the approach that is best suited to the needs and abilities of your particular class.

KEY



Statements:

1. Fish amphibians, mammals, reptiles, birds, and acorn worms all belong to the Phylum CHORDATA.
2. The largest and most complex subphylum of chordates is the VERTEBRATA which contains the animals with backbones.
3. The NOTOCHORD is a rod of connective tissue found along the dorsal side of chordates.
4. Since the backbone is composed of more than one bone, a better name for it would be the VERTEBRAL (column) column.
5. The anterior or head end of the nerve cord in chordates forms the BRAIN.
6. The paired GILL SLITS, (two words) or openings into the throat, are present at some time in all chordates.

7. The Amphioxus or LANCELET is a small fish-like animal.
8. The subphylum HEMICHORDATA contains the acorn worms which sometimes reach a length of over 2 meters.
9. Tunicates are placed in the subphylum UROCHORDATA because of their unique structures.
10. The central nervous system found in chordates develops from the nerve cord. The brain comes from the head end of the nerve cord while the remaining part becomes the SPINAL CORD (two words).

KEY WORDS

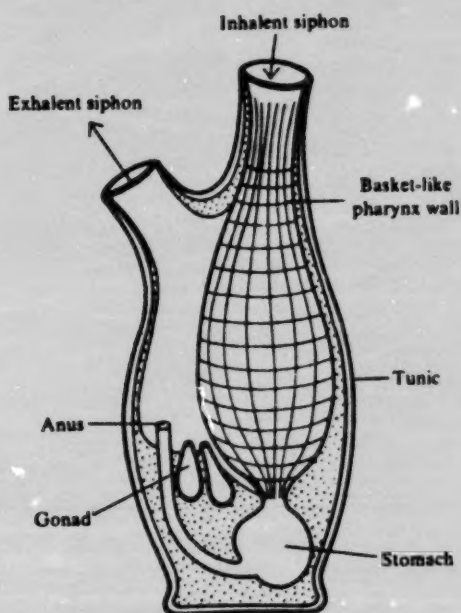
anterior
brain
Cephalochordata
Chordata
connective tissue
gill slits
Hemichordata
lancelet
nerve cord
notochord
spinal cord
tunicates
Urochordata
Vertebrata
vertebral column

THE CHORDATE CONNECTION

Fish, whales, turtles, sharks. These are the creatures we think about when we consider life in the sea. These and other, somewhat less impressive animals belong to the Phylum Chordata. This phylum has four subphyla. The largest and most complex subphylum is the Vertebrata which contains the fish, amphibians, reptiles, birds and mammals with which we are familiar. The other three subphyla are less well known and we will only look at them briefly:

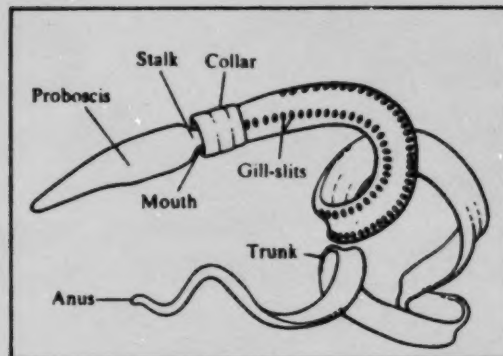


Urochordata - the tunicates are barrel shaped animals often attached to the bottom in shallow waters



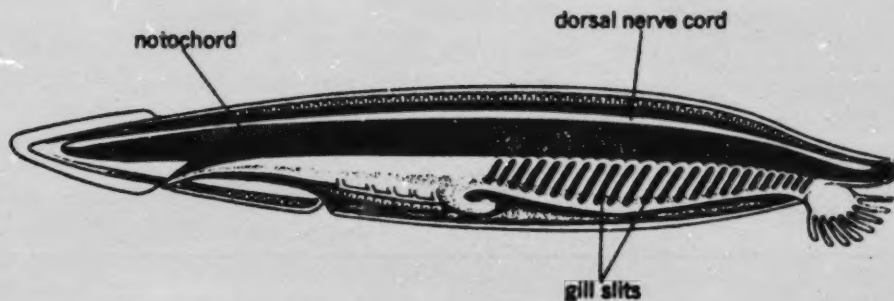
TUNICATES

Hemichordata - the acorn worms - these wormlike animals sometimes reach a length of over 2 meters.



ACORN WORM

Cephalochordata - Amphioxus, the lancelet, a translucent, fish-like animal about 5 centimeters long.



LANCELET

Tunicates, acorn worms, lancelet. These animals hardly look like blue whales or white sharks. Why have taxonomists placed all of these animals in the same group? Three factors make chordates different from all other animals:

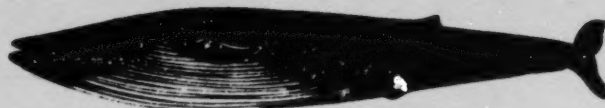
All chordate embryos have a rod of connective tissue along the length of the dorsal side of their bodies. This rod is called a notochord. In most vertebrates this notochord becomes the backbone or vertebral column which is part of the skeletal system.

All chordates have a tubular nerve cord. The anterior (head end) of the nerve cord develops into the brain. The remaining part becomes the spinal cord. The brain and spinal cord are parts of the nervous system.

All chordates have paired gill slits at some time in their lives. The gill slits are openings in the throat and may be present throughout life (as in the fish) or may only be present for a short time (as in a human embryo).

The chordates we will examine include man who does not really live in the sea. Man's influence on the marine ecosystem is so profound that we must consider him a prime animal for study.

A LOT OF NERVE



Most scientists view the chordates as the most complex and highly developed group of animals. Listed below are statements dealing with the Phylum Chordata. To find the words that fit into the blanks in these statements, start at the arrow in the diagram. Find the word for the first blank and circle it. Since the first word is horizontal, the second word will fit into it vertically. The third will fit into the second horizontally, and so on. Circle each word as you find it and also write it in the blank in the sentence.

L I F E I N V E R T E B R A T E S L E G I V S N S O A
 E F U T U B E G U B R A L A G E T A N I V E P E P S S
 E E R U C O R D E R A V M P I O A N H L C R I V I P D
 → C H O R D A T A S V I E W G L A N C E L E T N R N I O
 E E C O A N E A M E B R A I L E G E M A P E A O A H R
 P M H D C T B S E R O T W L S H E M I S H B L C L E S
 H I O B R E R O D T S E A B L O N E C O A R C O B A A
 A C R A O R A R M I N B R A I N O R H U L A O R R R L
 L H D C N O T O C H O R D O T H U R O C H O R D A T A
 O O A K E I A D E E W A R T S L T U R O C T D O I V O
 C R T E U R O D N A O L U M B A R A D O H A A R N N R
 H D A D R A T O T D N O W A R H E M A C O R D S O L T
 O T E N O R A N R E C H I D E R M A T A R V I A D C A
 R A I N N V A C O R N N O R M S A M A Y D O T L O A D

Statements:

1. Fish amphibians, mammals, reptiles, birds, and acorn worms all belong to the Phylum _____.
2. The largest and most complex subphylum of chordates is the _____ which contains the animals with backbones.

3. The _____ is a rod of connective tissue found along the dorsal side of chordates.
4. Since the backbone is composed of more than one bone, a better name for it would be the _____ column.
5. The anterior or head end of the nerve cord in chordates forms the _____.
6. The paired _____, (two words) or openings into the throat, are present at some time in all chordates.
7. The Amphioxus or _____ is a small fish-like animal.
8. The subphylum _____ contains the acorn worms which sometimes reach a length of over 2 meters.
9. Tunicates are placed in the subphylum _____ because of their unique structures.
10. The central nervous system found in chordates develops from the nerve cord: The brain comes from the head end of the nerve cord while the remaining part becomes the _____ (two words).



BIOLOGICAL FACTORS:

Cartilaginous Fish - The Sharks

512

612

TEACHER BACKGROUND - Sharks!

The number of papers, books, notes, letters, and articles on sharks is legion. The enormous number attests to the fascination that these creatures have held for man since we first noticed them thousands of years ago. Your students, as you will have already noticed, are not immune to this fascination. Popular works on the shark tend to exaggerate and distort the facts while technical and scientific works shroud the facts in complex and precise vocabulary unintelligible to the lay reader. The following reading strives to present the facts, without fantasy, in terms comprehensible to your students. With sharks, the facts can be fantastic enough. The article cited at the end of the student text serves as a good jumping off point for further exploration by you or by your students. The challenge for you will be to channel your students' natural enthusiasm into constructive avenues and out of paths which lead to the destruction of sharks. A comprehensive work which can supply you with ample ammunition for your battle is:

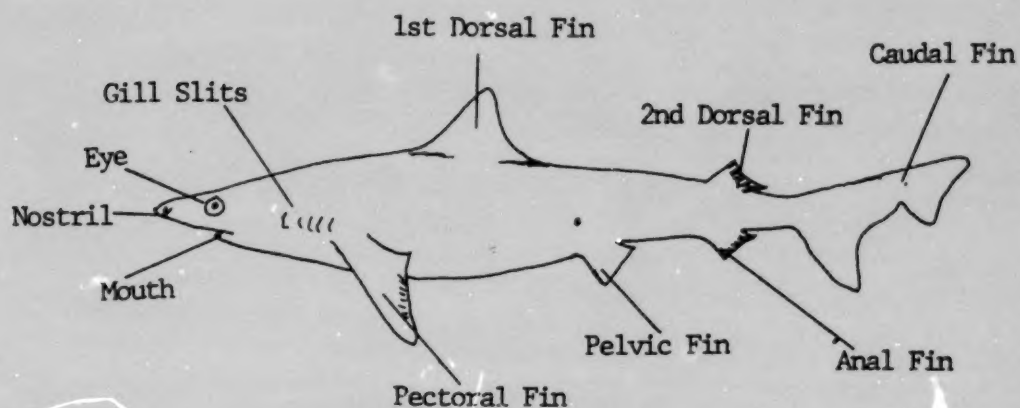
The Book of Sharks by Richard Ellis (1975). Published by Grosset and Dunlap. New York. 320 pages.

The "Shark Hunt" is a simple word search designed to reinforce the vocabulary introduced in the text. You may elect to have your students create word searches or crossword puzzles of their own. These activities have proven effective in increasing retention of new vocabulary and concepts.

Duplicate the text pages. One set is recommended per student. This activity is best accomplished by individual students and may be assigned as a homework assignment. The subject matter lends itself to further research by your students and you might consider assigning research papers on various aspects of shark behavior and biology. Plan to allot some time for a discussion of the material and to provide answers to the questions contained in the text.

KEY

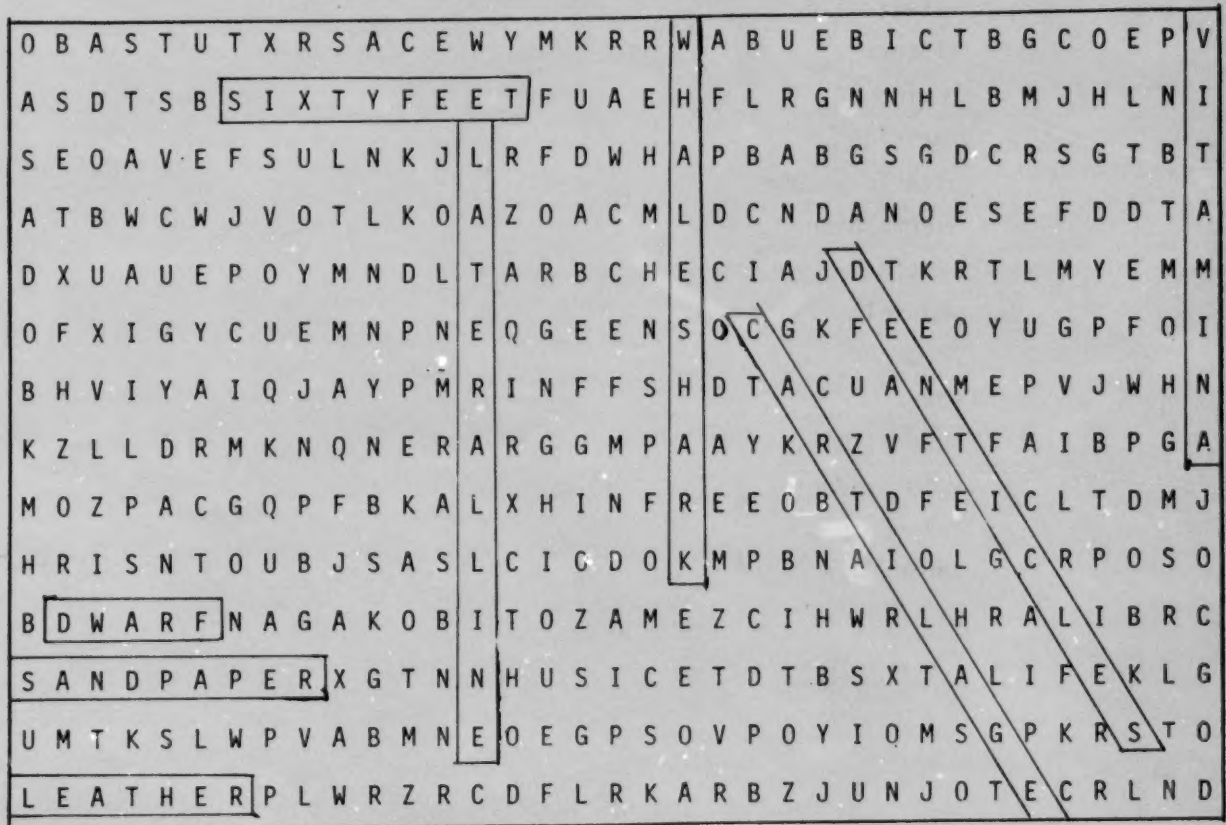
1. To many of your students, stripes will seem like an odd pattern for an animal that wants to hide. Stripes seem to provide an animal with camoflauge by breaking up the outline of the animal - the zebra is a good example of this phenomena. Striped sharks would reasonably be expected to be found in habitats with vertical or horizontal barring perhaps due to vegetation.
- 2.



3. The head shaking movement the shark uses in feeding turns the sharp teeth into miniature saws which can cut large chunks out of the prey.
4. The teeth in the second and third rows face posteriorly which may be of value to the shark in that these teeth act like barbs and hold the shark onto its prey. A secure bite and hold helps assure the shark of a successful hunt.
5. Cartilage provides several advantages to the shark: increased bouyancy, flexibility which allows the shark to change direction quickly and within a short space, and increased ability to change depths rapidly without risking fatal injury.
6. Since the majority of the shark's life is devoted to food gathering, it is probably safe to assume that all of the senses are used in some degree in the food getting operation. In particular, the senses of smell, "hearing" or vibration sensing, and vision play important roles in locating food.

- | 7. | Stimulus | Sense(s) |
|----|---|-----------------------------|
| | Splashing, yelling, or hitting rocks together underwater | <u>lateral line</u> |
| | Swimming where blood, vomit, bait or fish scraps are present. | <u>smell</u> |
| | Swimming alone rather than in groups. | <u>lateral line, vision</u> |
| | Touching or bothering the shark while swimming in a black-wetsuit. | <u>vision, lateral line</u> |
| 8. | This is a question with no right or wrong answers since it asks for student opinion. Use the question for a discussion of the issues involved in changing public opinion regarding the role of sharks in the marine ecosystem. The author's bias is, of course, that education can change people's attitudes. Hopefully, you share that bias. | |

Solution to "Shark Hunt"



KEY WORDS

bouyant
carrion
cartilage
caudal
Chondrichthyes
Chordata
convulsing
cranium
dermal denticles
dorsal
erratic
eviscerated
gamut
immune
iridescent
lateral line
litters
luminous
membrane
olfactory lobes
overfishing
pectoral
physiological
predator
shark
susceptible
swim bladder
taxonomists
Vertebrata

SHARKS!



"Actually, sharks aren't half bad once you get to know them."..... Gary Soucie

SHARK! The word triggers the imagination - the big, streamlined torpedolike body, gray above and white below, propelled silently through the water, the slack grin of its mouth opening to reveal rows of sharp, pointed teeth. What is the reality of our image? Aside from a few physiological facts, little can be said with confidence about sharks that applies to all species and individuals.

In size alone, sharks range from the dwarf shark, which is six to eight inches when full grown, to the whale shark, the biggest fish in the sea, whose length reaches at least 45 feet and probably 60 feet. In shape, sharks run the gamut from the eel-like to the lumpy.

6"

Dwarf Shark

60'

Whale Shark

Shark colors range from midnight black through all sorts of grays, blues, browns and olive drabs to iridescent green. They may be of a solid color, dark above and light below, or marked with spots, speckles, bands, bars, reticulated (squares) patterns, zebra or tiger stripes. At least one shark has eyes that glow in the dark and a few others have luminous bodies.



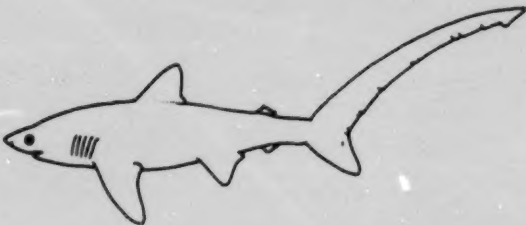
Tiger Shark.



Chain Dogfish

1. Many sharks match the place in which they live. Where might you expect to find a striped shark?

While all sharks have tails or caudal fins with upper lobes that are longer than the lower, there is a great variety in the size and shape.



Thresher Shark



Nurse Shark

Similarly, the pectoral fins show a wide range of size and shape.

PECTORAL FINS



Sickle Shark



False Catshark



Gulper



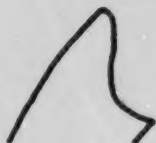
Atlantic Angel
Shark

Sharks may have one or two dorsal fins and these, too, may be large or small, in several shapes other than triangular and, in the case of the sleeper sharks, floppy rather than stiffly erect.

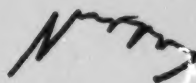
DORSAL FINS



Sleeper Shark



Sawshark

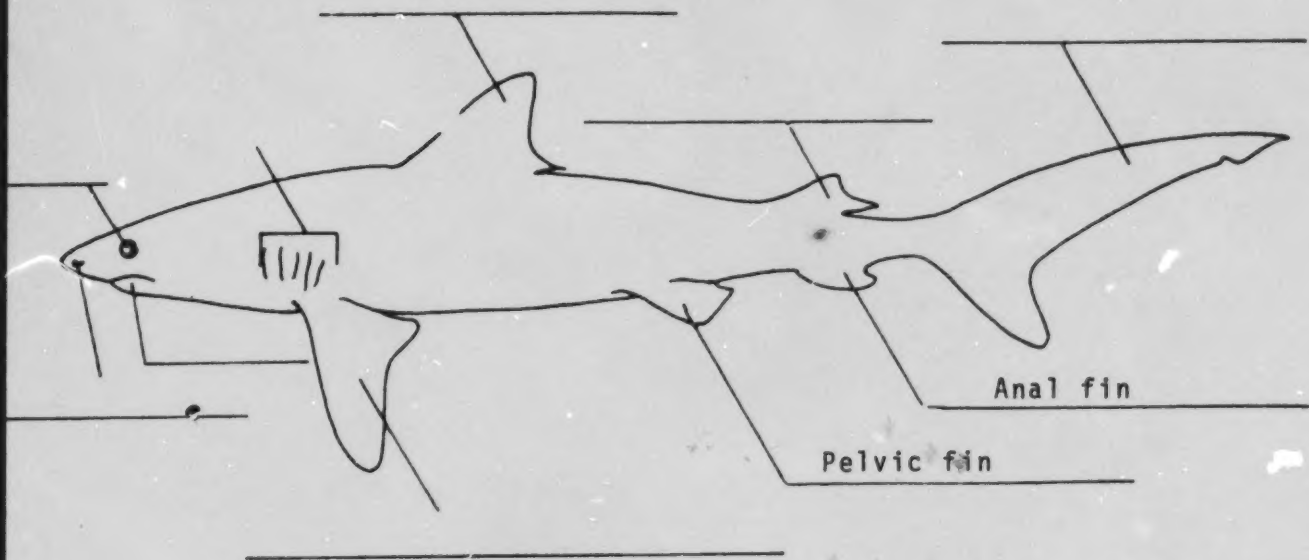


Black Dogfish



Oceanic
Whitetip

2. The silhouette below shows a typical shark. Locate and label the eye, gill slits, first and second dorsal fins, caudal fin, pectoral fin, and the mouth and nostril. The remaining fins are labeled for you.

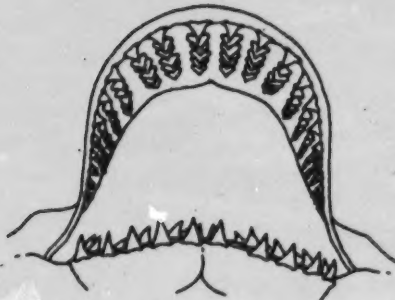


Sharks are famous for their teeth. The teeth may be large or small, triangular, crescent-shaped, awl-shaped or flattened. Some sharks have both cutting and crushing teeth. The teeth are, in reality, highly modified versions of the countless hard, sharp, pointed "scales" or dermal denticles which cover the shark's skin. The teeth are not rooted in the jaws and in fact, the upper jaw is not fused to the cranium (skull). Because of these loose, but strong and flexible connections between the jaw and cranium, some sharks open their mouths until their snouts are virtually perpendicular. With the mouth wide open, the jaws protrude forward of the body and the teeth somewhat forward of the jaws. So, contrary to one of the oldest shark myths, sharks do not have to roll

over to bite a big object. Attacking straight on, ten foot sharks have been observed taking bucket sized, twenty pound chunks out of huge whale carcasses, their shaking heads and convulsing bodies turning their teeth into miniature saws. The resultant bites are hemispherical and look as if they had been made by an enormous ice cream scoop.

3. What is the role of the head shaking movement in feeding?

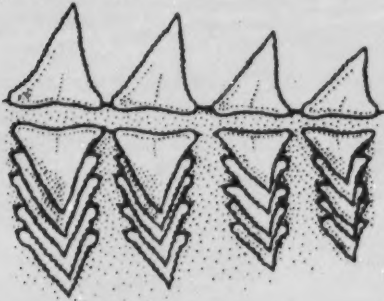
Sharks sometimes lose teeth in feeding. To compensate for these losses, sharks have six to fifteen rows of teeth, one to several of which are erect and functional. The other rows lie in reserve, flattened beneath a thin membrane. These new rows of teeth move forward to replace teeth that are lost. In some species, the teeth are replaced periodically so that the shark's business teeth are always sharp and new. The triangular, serrated teeth so many sharks have are the most efficient cutting instruments known in nature.



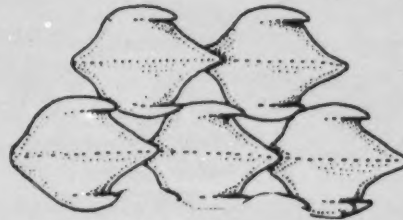
Looking down the throat.



If a tooth is lost, a spare is ready to take its place.



A great white shark's spare teeth lie flat in rows inside its jaw and are covered by a membrane.



The scales on its body are of the same tough material.

4. The side view of the shark jaw shows the positioning of the rows of teeth. How might the way in which the second and third rows of teeth face be of survival value to the shark?

Taxonomists group sharks into some 250 to 350 species. The number varies because authorities differ in their opinions. These differences underlie our general lack of knowledge about sharks. Sharks fall within the subphylum Vertebrata of the phylum Chordata. Taxonomists place the sharks along with the skates and rays in the

Class Condriichthyes, a term that is comprised of the Greek words for "cartilage" (chondros) plus "fish" (ichthyes). The Class name tells us something important about sharks. Their boneless skeletons are made of cartilage, a lighter and more flexible substance also found supporting our ears, making the end of our nose and cushioning our knee joints.



Common Skate

This bonelessness is the most important way in which sharks differ from other fish (those belonging to the Class Osteichthyes, "bony fish"). Cartilage is lighter and more bouyant than bone. Sharks lack the swim bladder that most fish have for bouyancy. The cartilage skeleton helps make up for this deficiency while enabling the shark to change depths rapidly without risking fatal injury due to expansion of the swim bladder. The ability to change depths rapidly is an obvious advantage to a

predator on other fish. The cartilaginous shark is a supple fish, able to reverse direction quickly and within a short space. This maneuverability compensates for the shark's inability to swim backward or stop quickly. Unfortunately, the flexible cartilage which forms the shark's frame has trouble supporting the weight of the internal organs when the shark is out of the water. Even after a few minutes, the shark will suffer fatal injury and shock.

5. What are three ways in which the cartilaginous skeleton helps the shark survive?

How does this steely eyed "eating machine" sense its surroundings? We actually know very little. We do know that sharks can smell quite well. The olfactory lobes of the brain which are the center of the sense of smell may make up two-thirds of the total brain weight in sharks. Because of this information we think that the sense of smell is very important to the shark in locating food. "Hearing," or at least vibration detection, is important for sensing changes in the surroundings. Vibrations such as those that an injured and struggling

fish might produce are received in specialized sense organs located along the side of the shark in the lateral line. We don't know how well the shark can see or the role of vision in its life. We also don't know whether the shark possesses a true sense of taste, even though it "tastes" a lot of things - finfish, squid, molluscs, crustaceans, echinoderms, jellyfish, seaworms, skates and rays, other sharks, sea turtles, seabirds, seals, the occasional land animal that wanders into the ocean at the wrong time and place, as well as a certain amount of garbage, carrion and indigestible junk.

6. What are three of the senses the shark uses to locate food?

Our lack of knowledge about the manner in which sharks behave makes us say that sharks are unpredictable. If we knew more, we'd probably be able to say that their behavior is fairly predictable. We'd like to know more because a very small amount of this seemingly unpredictable behavior is directed at man.

Shark attacks against humans are extremely rare events. The number of shark attacks around the world averages only about 26 per year. Only 29 percent of the attacks are fatal. About three-fourths of the victims are left bleeding and helpless, but uneaten, in the water after receiving a single bite. Twenty-six attacks out of some

four billion humans worldwide is not a very high percentage. Still, when you're swimming in the surf, it's small comfort to know that four times as many people are struck by lightning in the United States alone than are bitten by sharks in all of the waters of the world each year. Shark attacks are unlikely and unwelcome.

No shark can be called a man-eater in the sense of customarily feeding on human flesh. Scientists think that usually when sharks bite people with supper in mind, it is a case of mistaken identity. Black-wetsuited divers look a lot like seals, a favorite prey of sharks. A person dangling arms and legs from an air mattress or surfboard may look like a sea turtle or a big, eviscerated fish. The erratic splashing of a frolicking surf-bather may seem to a shark like the frantic thrashing of a sick or wounded fish. We don't know for sure. The Navy and Air Force have spent considerable sums of money in trying to find out.

7. Swimmers frequently encounter sharks. All of the actions listed below are things to avoid, if you see a shark. Next to the action, list the sense or senses (smell, lateral line, vision) the shark probably uses to react to the stimulus:

<u>Stimulus</u>	<u>Sense(s)</u>
Splashing, yelling, or hitting rocks together underwater	_____
Swimming where blood, vomit, bait or fish scraps are present	_____
Swimming alone rather than in groups	_____
Touching or bothering the shark while swimming in a black wetsuit	_____

Prejudice against sharks is so strong that most of us overlook their positive contributions to man. For centuries sharks have been used as food, fertilizers and hides; as a source of vitamins and medicines; and in cosmetics and costumes. The annual commercial catch of sharks exceeds 1.2 billion pounds. The shark provides much of the "fish" for fish and chips. It also is providing scientists with ammunition in the battle against cancer; - most sharks seem to be virtually immune to the disease. Interest in shark exploitation is increasing.

Because of the relatively small litters, the long time it takes to grow to sexual maturity, the regular migration routes or easily fished habitats of so many species and their relatively small population sizes, sharks are particularly susceptible to overfishing. So it appears that the shark has more to fear from man than man has to fear from the shark. In our ignorance of shark biology and behavior, we run the risk of destroying this magnificent balancing agent of the seas.

8. In your opinion, how can people's attitudes toward sharks be changed?

WANT TO LEARN MORE ABOUT SHARKS?

Much of the information in the preceding section comes from the following article, used by permission, which you can read for yourself:

"Consider the Shark," article by Gary Soucie with paintings by Gary Ellis. Audubon Magazine, September, 1976: Volume 78, number 5. Pages 2-35. Copyright 1976 - The National Audubon Society.

This article is entertaining reading and beautifully illustrated.

SHARK HUNT

Here are clues to words that are hidden in the "Shark hunt". They may be written across, up and down, or sideways. Find as many as you can and draw a box around each word as shown. Some of the boxes may overlap. Happy shark hunting!

Clues

The smallest shark
 What a shark's skeleton is made of
 The largest shark
 A shark's skin feels like this
 The "teeth" on a shark's skin
 From the oil of shark's livers
 Made from sharkskin
 Size of the largest shark

_____ organs sense vibrations

O	B	A	S	T	U	T	X	R	S	A	C	E	W	Y	M	K	R	R	W	A	B	U	E	B	I	C	T	B	G	C	O	E	P	V
A	S	D	T	S	B	S	I	X	T	Y	F	E	E	T	F	U	A	E	H	F	L	R	G	N	N	H	L	B	M	J	H	L	N	I
S	E	O	A	V	E	F	S	U	L	N	K	J	L	R	F	D	W	H	A	P	B	A	B	G	S	G	D	C	R	S	G	T	B	T
A	T	B	W	C	W	J	V	O	T	L	K	O	A	Z	O	A	C	M	L	D	C	N	D	A	N	O	E	S	E	F	D	D	T	A
D	X	U	A	Q	E	P	O	Y	M	N	D	L	T	A	R	B	C	H	E	C	I	A	J	D	T	K	R	T	L	M	Y	E	M	M
O	F	X	I	G	Y	C	U	E	M	N	P	N	E	Q	G	E	E	N	S	O	C	G	K	F	E	E	O	Y	U	G	P	F	O	I
B	H	V	I	Y	A	I	Q	J	A	Y	P	M	R	I	N	F	F	S	H	D	T	A	C	U	A	N	M	E	P	V	J	W	H	N
K	Z	L	L	D	R	M	K	N	Q	N	E	R	A	R	G	G	M	P	A	A	Y	K	R	Z	V	F	T	F	A	I	B	P	G	A
M	O	Z	P	A	C	G	Q	P	F	B	K	A	L	X	H	I	N	F	R	E	E	O	B	T	D	F	E	I	C	L	T	D	M	J
H	R	I	S	N	T	O	U	B	J	S	A	S	L	C	I	O	D	O	K	M	P	B	N	A	I	O	L	G	C	R	P	O	S	O
B	D	W	A	R	F	N	A	G	A	K	O	B	I	T	O	Z	A	M	E	Z	C	I	H	W	R	L	H	R	A	L	I	B	R	C
S	A	N	D	P	A	P	E	R	X	G	T	N	N	H	U	S	I	C	E	T	D	T	B	S	X	T	A	L	I	F	E	K	L	G
U	M	T	K	S	L	W	P	V	A	B	M	N	E	Q	E	G	P	S	O	V	P	O	Y	I	Q	M	S	G	P	K	R	S	T	O
L	E	A	T	H	E	R	P	L	W	R	Z	R	C	D	F	L	R	K	A	R	B	Z	J	U	N	J	O	T	E	C	R	L	N	D

Acknowledgements

"Shark-Hunt" is adapted from "Shark Facts", a Florida 4-H Marine Science Special Interest Series publication by Mrs. Carolee Parmer.

TEACHER BACKGROUND - A Shark Study

If you have been faithfully teaching the other lessons in marine science, you have probably already reached the conclusion that for your students the shark provides a stimulation unequalled by any other animal of the sea. "A Shark Study" provides your students with an opportunity to observe a shark first hand. During the course of this activity it is recommended that you work toward dispelling the "Jaws" mentality that many of your students will have. Sharks play an important role in the sea. We can be fairly certain that if all the sharks were removed, the disruption caused in the seas would result in a major collapse in the marine food web. Emphasize the role of the shark and the fact that shark attacks on man, while horrible, are exceedingly uncommon. Strive to replace ungrounded fears with fact. An excellent treatment of sharks and our outlook toward them may be found in an article by Gary Soucie printed in Audubon magazine (September 1976. Volume 78: Number 5. pages 2-35).

"A Shark Study" lends itself to completion in two class periods. One period is devoted to external anatomy, one period to internal anatomy. If time allows, it is possible to expand this activity by increasing the depth of study of the circulatory system and incorporating a dissection of the brain and central nervous system. The activity may also be supplemented by reading research into shark biology.

Preserved sharks may be obtained from the biological supply houses listed at the end of this section. If you live near the coast or have contact with sport or commercial fishermen you can arrange to have them provide you with small sharks or with shark embryos from larger sharks. Donated sharks are best preserved via freezing but they can be preserved in ordinary fixative if no freezer facilities are available.

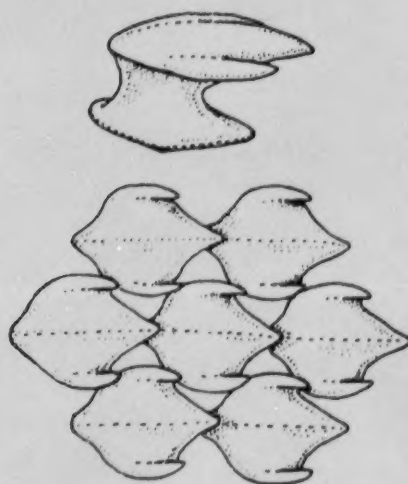
Duplicate the activity pages. One set is recommended per student. If your class is unaccustomed to dissection, review general techniques and safety instructions before you begin. Demand a respect for the specimens to be dissected and tolerate no mutilation. Ideally, students should work in pairs. Practically, four students per shark is a reasonable group size. Provide any dissection guides you may

have, especially those with good drawings or photographs of the internal organization of the dogfish shark. Circulate through the laboratory area while your students perform the activity. Be available for aid and to set the proper tone. Plan to allow class time for a discussion of the techniques and to provide answers to the questions found within the instructions and in the "Analysis and Interpretation" section. With a small amount of advance planning, this activity can prove to be one of the most exciting of the year.

KEY

Part I - External Anatomy

- 1, 2 Answer depends upon experimental observations.
- 2.a. The caudal fin provides the power for swimming. While sharks are active swimmers, in general they are not very powerful swimmers.
- 2.b. Most dogfish possess two dorsal spines, one at the base of each dorsal fin. Since the dogfish is a bottom dweller, the fins may provide protection from being eaten (or "stepped" on) from above.
3. Answer depends upon experimental observations.
- 4.a. While the answer depends upon the experimental observations, the drawing should be similar to the following:



- 4.b. The dermal denticles are "toothed" and overlap in such a manner that movement from the anterior toward the posterior encounters much less resistance.
- 4.c. Answer depends upon experimental observations. Countershading (dark dorsal side, lighter ventral side) is a common phenomenon in the dogfish.
- 5. Teeth are present on both the upper and lower jaw.
- 5.a.b. Answer depends upon experimental observations. While the teeth are arranged in rows, the number of rows varies between individuals. The teeth "unfold" from the back as the rows move forward so that a single shark may have teeth that point backwards in the posterior rows of teeth and teeth that point forwards in the anterior rows.
- 6. The water circulation in the nostril serves to bring food molecules in contact with sensitive neural receptors. The shark has been described as a "swimming nose". The sacs increase the receptor covered surface area. When a shark takes water into its mouth to aerate its gills, suction causes some water to flow in and out of each olfactory sac. In addition, the forward motion of the shark brings water through the nostrils into the sacs. All of these mechanisms increase the shark's ability to sense its environment.
- 7. Unlike most mammalian eyes, shark's eyes have vertical pupils.
- 8a.,b. Answer depends upon experimental observations.

Part II - Internal Anatomy.

- 2.a. The liver is the largest visceral organ.
- 2.b.; 3.a.,b.; 4.a.,b.; 5.a. Answer depends upon experimental results.
- 5.b. The pancreas is usually tan in preserved specimens while the spleen is gray. Variation is possible and the final answer must depend upon observation.
- 6.a.,b. Answer depends upon experimental observations.

- 7.a. Yes, the heart is separated from the other organs by a thin transverse septum just anterior to the liver.
- 7.b. The pericardial sac functions to cushion the heart and provide lubrication which keeps the heart muscle from abrading (or being abraded by) surrounding tissue. Your students may have other suggestions.
- 8.a., b, c. Answer depends upon experimental observations.
- 9.a. The sinus venosus enters the atrium.

Analysis and Interpretation

- 1.a., b, c, d. Answer depends upon experimental observations.
- 2. Shark coloration seems to serve the general role of camouflage which allows sharks to approach their prey undetected.
- 3. The several rows of teeth, each with a slightly different orientation provide an effective barb system that helps prevent the prey from escaping. The teeth which face posteriorly are particularly effective in preventing escape.
- 4. Because of the dramatic biting and head shaking feeding pattern (coupled with frequent attacks on tough materials) sharks often lose teeth. The ability to replace lost teeth guarantees that the shark will continue to have teeth to use in preying upon other animals. If the teeth were not replaced, each tooth loss would mean a reduction in the effectiveness of the shark's predatory abilities.
- 5.a. Answer depends upon experimental observations.
- 5.b. Scientists are not in total agreement concerning how the lateral line functions and its role in the life of the shark. Evidence seems to indicate that the sensing of vibrations is important in locating prey, locating enemies, locating mates, and in navigating. Your students may have additional suggestions.
- 6.a. The shark adjusts its buoyancy by varying the oil content in the liver. Buoyancy is also related to the cartilaginous skeleton.
- 6.b. Having a swim bladder could indeed be a disadvantage to the shark. The shark needs to be able to rapidly change its depth in the pursuit of prey fish. Rapid changes in depth cause rapid changes in pressure which cause rapid changes in the size of the air bladder. The changes can be so extreme as to kill bony fish. Since sharks do not possess swim bladders, they are able to avoid this danger.
- 7. The ridged inner lining of the stomach aids in kneading the stomach contents in preparation for later absorption.

8. The spiral valve increases the effective length of the digestive tract without having to increase the actual length. The spiral valve greatly increases the absorptive area.
9. This question is designed to provide an opportunity for discussion about shark population dynamics and the role of sharks in the marine ecosystem. Overfishing of immature sharks may indeed change the population structure. When the present older sharks die, there may be fewer immature sharks to replace them causing a net reduction in the population. It is important for your students to realize that sharks play an important and beneficial role in the sea. They are not likely to destroy other fish populations. We need to remember that these other populations have coexisted and benefited from the presence of sharks for millions of years. It appears that man is a greater danger to fish (and shark) populations than sharks could ever be.

KEY WORDS

anal fin
anatomy
anterior
atrium
buoyancy
calipers
cartilage
caudal fin
Chondrichthyes
clasper
cloaca
dermal denticles
dogfish sharks
dorsal fin
embryo
forceps
gestation
gonads
incision
internal fertilization
intestine

lateral line
 liver
 median
 nostrils
 oviduct
 pancreas
 pectoral girdle
 pectoral fin
 pelvic fin
 pericardial
 posterior
 prey
 ratio
 scalpel
 sensory receptors
 sphincter
 sinus venosus
 spleen
 spiral valve
 stomach
 swim bladder
 Vertebrata
 ventral
 ventricle
 vibration
 viscera

Shark sources:

Carolina Biological Supply Company
 Powell Laboratories Division
 Gladstone, Oregon 97027
 (503) 656-1641

and

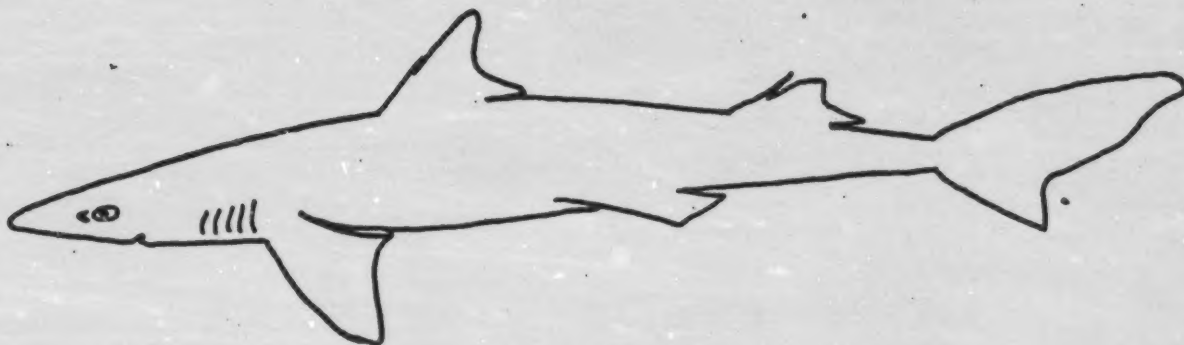
Main Office
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Ward's of California
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 Monterey, California 93940
 (408) 375-7294

A SHARK STUDY

Dogfish sharks are found along both the Pacific and Atlantic coasts. These sharks reach a maximum size of about 5 feet in length. As with most sharks, the females reach a greater size than the males. While they are active swimmers, dogfish usually remain in a limited area. Dogfish are active feeders, dining on herring, pilchard sardines, anchovies, smelts, sandlances and other small fishes, squid and crustaceans. They have also been known to feed on cannery wastes and other refuse dumped into the sea.

Sharks belong to the class Chondrichthyes of the subphylum Vertebrata. Sharks and other members of this class possess a skeleton made of cartilage. The dogfish most likely to be encountered on the Pacific coast is the spiny dogfish, Squalus acanthias



Squalus acanthias

Reproduction in the dogfish involves internal fertilization of three to fourteen large eggs. The eggs develop within the body of the female shark inside the enlarged oviduct. The gestation (development) period is nearly two years. The fact that any one female can therefore only breed once every two years is important in considering the likelihood of overfishing. The developing dogfish use stored yolk material for energy. When development is complete, the young sharks emerge as miniature adults.

Dogfish have sporadically been of commercial value. During World War I, dogfish meat was canned under the trade name "Gray Fish". "Gray Fish" never became a big seller, most likely because improper handling causes canned dogfish to produce ammonia which isn't exactly the aroma most chefs are looking for when they prepare dinner! During World War II, dogfish were extensively fished for their livers. The livers are rich in Vitamin A and pilots were given extra doses in hopes of improving their vision. The shark liver business boomed for a few years, only to collapse again when a synthetic vitamin A was developed. Since the middle 1970's a small commercial fishery for dogfish has processed the fish for shipment to England and other European countries where the flesh becomes the "fish" of "fish and chips".

In the following activity you will see part of another use of the dogfish shark - dissection. Many of our physicians and surgeons received their first anatomical training using the dogfish as a subject. While the absolute number of sharks used in anatomy classes is small, the role they play is great. Careful technique will enable you to learn much about the structure and workings of the vertebrate body.

Materials:

shark or late term shark embryo

dissecting pan

paper towels

dissecting kit (scalpel, forceps, probes, scissors)

scales or balance

ruler and calipers (if available)

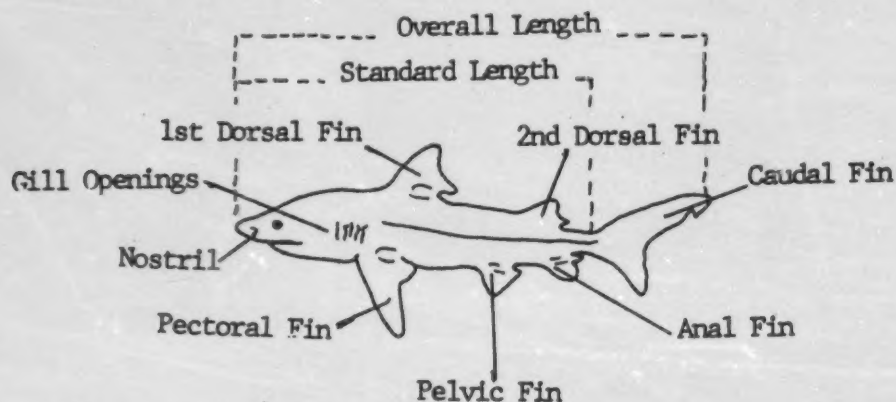
anatomical charts

dissecting microscope

Procedure:

I. External anatomy

Use the following diagram to help you identify the structures mentioned:



1. Obtain a dogfish shark and record the following data:

Common name	Scientific name
Length overall _____	cm.
Standard length _____	cm.
Width at head _____	cm.
Width at posterior (side away from head) to pectoral fins _____	cm.
Width at beginning of caudal fin _____	cm.
How would the streamlining you've just measured be helpful to the shark as predator? _____	

2. In the space below sketch the shape of the fins listed:

1st dorsal fin

pectoral fin

pelvic fin

caudal fin

2nd dorsal fin

anal fin

- a. Which fin provides the power for swimming?

- b. Are any of the fins equipped with spines? _____

If so, which one(s)? _____

3. Examine the pelvic fins on your shark and those on other sharks available. In male sharks, the median edge (edge toward the midline of the fish) is modified to serve as a reproductive organ. This reproductive organ is called the clasper.

- a. Is your shark a male or a female? _____

- b. Record the sex of your shark in the space on the blackboard designated by your teacher.

4. Use your scalpel to cut a 1 cm. square below the dorsal fin. Cut just deep enough to pass through the skin. With the aid of your forceps remove the square of skin from the underlying tissue. Use a dissecting microscope to examine the shark skin.

- a. The "scales" you see are called dermal denticles (literally "skin teeth"). In the space below draw an example of the dermal denticles:

- b. Gently pass your hand along the surface of the shark's skin in an anterior to posterior (head to tail) direction. Then, pass your hand gently from the posterior to the anterior. Which direction provides the least resistance? _____

How might the dermal denticles you observed under the microscope provide an explanation of any differences you noticed in the ease with which you could move your hand across the skin's surface?

- c. What color is the dorsal ("top") surface of the shark? _____

Is the ventral surface ("bottom") the same color?

If not, what color is the ventral surface? _____

5. Open the mouth of the animal. Do you see any teeth?

With the mouth held open, feel for the presence of teeth with a finger tip. Are teeth present on both the upper and lower jaws? _____

- a. In the space below, draw a detailed series of shark's teeth:

- b. Are the teeth arranged in rows? _____
If so, how many? _____. Do the tips
of the teeth point toward the opening of the mouth,
away from the opening of the mouth? Or bothways?
- _____
- _____

6. Locate the paired nostrils. Gently insert a blunt probe into one of the nostrils. Water circulates through the small sac that you can feel within the nostril.

How might the water circulation help the shark in locating food?

7. Examine the eyes.

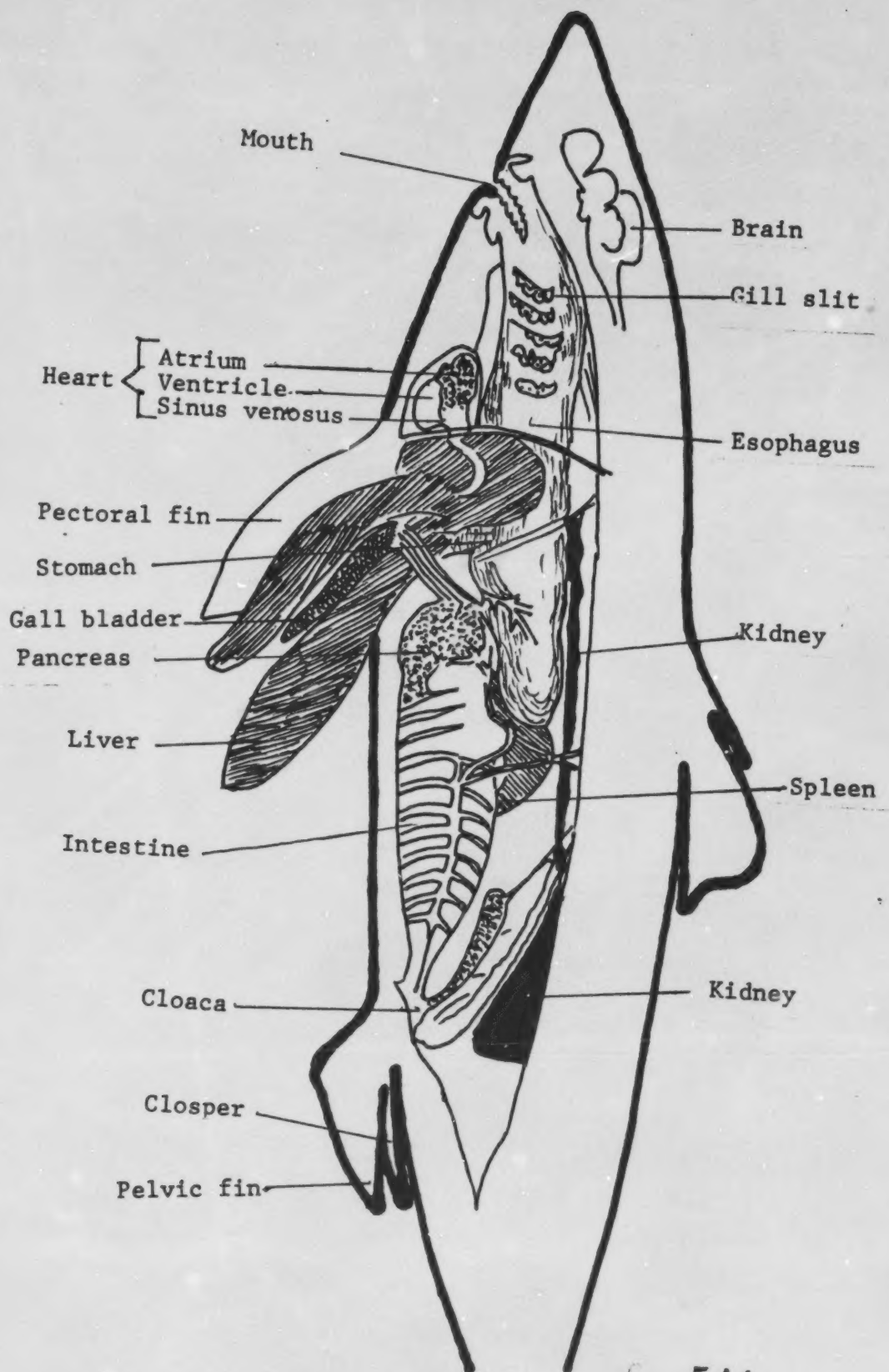
How do they differ from mammalian eyes like ours?

8. a. Locate the lateral line, a series of sensory receptors, on each side of the shark. The lateral line senses vibrations in the water. What is the overall length of the lateral line in your specimen? _____
- b. Use the overall length of your shark (from number 1) to determine the percentage of the total length occupied by the lateral line.

$$\begin{array}{l} \text{(Hint: \% of body length} \\ \text{occupied by} \\ \text{lateral line} \end{array} = \frac{\text{length of lateral line}}{\text{overall body length}} \times 100)$$

II Internal Anatomy

1. Pin your shark, ventral side up, firmly in a dissecting tray. Use your scalpel and scissors to make an incision through the skin along the midline. Start at the cloaca (the opening between the pelvic fins) and proceed anteriorly up to the pectoral girdle (a cartilage structure at the level of the pectoral fins). Be careful not to cut deeply below the skin. Expose the viscera (internal organs) by holding back the lateral flaps of belly skin and making incisions from the ventral side to the dorsal side. Pin back the flaps of belly.
2. Use the diagram on the next page to find the liver. The liver stores food and oil high in vitamin A. Sharks can change the oil content of their livers to adjust their buoyancy (how they float).



- a. How does the size of the liver compare with the sizes of other visceral organs? _____
 - b. How many lobes are present? _____
 - c. What color is the liver? _____
3. Remove the liver by carefully cutting the attachments to the body wall and to other organs.
- a. Use a scale or balance to determine how much the liver weighs. Record the weight: _____ gm.
 - b. What percentage of total body weight consists of liver alone?
(Hint: you can find the percentage using the same technique you used in number 8, part 1.)
4. The stomach is located immediately posterior to the liver. Locate the stomach and open it with a longitudinal incision.
- a. Does the stomach contain food? If so, what is present? _____
 - b. Describe the internal appearance of the stomach:

5. The intestine begins at the posterior end of the stomach where there is a muscular valve (sphincter) and extends to the anus inside the cloaca. The intestine forms an S-shape and then suddenly enlarges. The spleen and the pancreas are attached at the bends of the S. Inside the enlarged portion there is a spiral membrane which greatly increases the absorptive surface without increasing the length of the intestine. This membrane

is called the spiral valve and is not found in bony fishes.

- a. How long is the intestine? _____ cm.
- b. The spleen which is an important site of blood formation is usually gray. What color is the pancreas? _____. The pancreas produces important digestive enzymes.

Make an incision up the intestine to expose the spiral valve. In the space below, sketch the spiral valve:

6. a. Most of the sharks will be too small to be sexually mature. If the reproductive organs are present, you will find them filling the dorsal part of the body cavity. Are the gonads (testes in the male; ovaries in the female) present in your specimen? _____
If so, what sex is your shark? _____
- b. Does this answer agree with your answer in 3a? _____
7. Use your sturdy scissors to cut through the cartilage of the pectoral girdle. Fold back the skin flaps. Locate the heart within the pericardial cavity.
- a. Is there a partition separating the heart from the other organs? _____
- b. The sac around the heart is called the pericardial sac. In life, it is filled with fluid. What is the likely function of the pericardial sac? _____

8. Remove the pericardial sac.
- a. What is the length overall of the heart? _____ cm.
- b. What is the width overall of the heart? _____ cm.
- c. Find the sinus venosus which carries blood to the heart. Does it enter the heart on the anterior or posterior end? _____

9. Carefully open the heart. The atrium of the heart is the receiving chamber for the blood. While the ventricle of the heart pumps blood to the body
- a. Locate the atrium. Which blood vessel enters this chamber? _____
- b. In the space below, draw and label a shark heart.

10. Return your shark and thoroughly clean your equipment and work area.

Analysis and Interpretation

1. Use the male/female information on the black board to answer the following questions:

a. What is the ratio of males to females?

males: _____ females: _____

b. How many males were present per female? (Hint: Divide the number of males by the number of females)

_____ males present per female.

c. Sex ratios are usually expressed in terms of number of males per hundred females. Express your results in these terms by multiplying your answer in number 2 by 100:

_____ males: 100 females.

d. These sharks were probably caught with baited hooks. From your answers above would you say that the fishing gear selects one sex over the other? _____

If so, which sex is taken more frequently? _____

2. Sharks come in all varieties of colors and patterns. How might the coloration of your shark help it to survive and be successful in its mode of life?

3. How does the positioning of the shark's teeth reduce the chance that the bitten prey will escape?

4. Sharks are active feeders and will attack and eat all types of sea life as well as some non-living items. Is the shark's ability to replace lost teeth of value to the shark? _____

How? _____

5. The lateral line extended over what percentage of your shark's body? _____%

The length may give us a clue to the importance of this sensory mechanism. What are two ways in which sensing vibrations in the water contribute to the shark's survival?

A. _____

B. _____

6. Most bony fish possess a swim bladder to help them adjust their buoyancy. Rapid changes in depth can cause the bladder to swell even to the point of killing the fish.

a. What is one way in which the shark adjusts it's buoyancy? _____

b. Consider the way sharks feed and what they feed upon. Could having a swim bladder be a disadvantage for the shark? _____

How? _____

7. The stomach begins the chemical breakdown and mechanical churning of the food. How might the internal structure of the stomach aid in this process?

8. What is the role of the spiral valve? _____

9. Most sharks used for dissection are sexually immature.

a. If most of the sharks taken by fishermen are also immature, is there a danger that fishermen are creating a population with few young sharks and more older sharks?

b. If all or most of the young sharks are captured, what will happen to the shark population when the older members die? _____

TEACHER BACKGROUND - "The Behavior of Sharks" - Main Ideas

"The Scientific American" article, "The Behavior of Sharks" provides your students with an opportunity to observe the research process as applied to shark behavior. The article contains accounts of several research projects and their results. Use this article to reveal additional shark biology and to reveal the way in which scientists set out to attack and solve a problem.

Writers of science tend to present a main idea in each paragraph, usually in the first sentence. These main ideas are supported by details which may be a series of events, examples, reasons, explanations, or causes and effects. The ability to extract the main ideas is critical to comprehension. "The Behavior of Sharks" will be difficult reading for many of your students. The following reading guide is presented as an aid to comprehending the materials in the article and to provide practice in analyzing main ideas and details and their relationships.

Duplicate the pages of the guide. One set is recommended per student. Spend a few minutes describing what is expected of the student. Suggest that the students read the statements in the three level guide before they read the article. In this way, the statements serve as a preview and your students will be looking for and expecting to see certain concepts. You may elect to have your students compare their answers by meeting in small groups. The process of resolving differences in opinion can be very instructive. Upon completion of the reading and the guide, discuss the guide by reference to the article. It is sometimes helpful to have your students note the page number and paragraph number where they found evidence supporting or refuting the statements in the guide. You can require your students to provide this information or you can offer extra credit for those that include it. Choose the technique that most appeals to you and best fits the needs and skills of your class. Which ever technique you choose allow time for a class discussion of the article and guide.

KEY - A correctly completed guide follows the "KEY WORDS" section.

KEY WORDS

adaptation

behavior

detail

distinguish

generalize

habitat

lateralis system

lateral line

main idea

nigrosene dye

nostril

siphon

KEY

"THE BEHAVIOR OF SHARKS" - Main Ideas

PART 1

Directions: In the article "The Behavior of Sharks", Perry W. Gilbert presents several main ideas and many supporting details about sharks. Before you read the article, read the items that are listed below. Items one, two and three are main ideas discussed in the article. Items A through I are supporting details. In front of each detail, write the number or numbers of the main idea or ideas which are supported by the detail. Indicate numbers of the page and paragraph which contain information that justifies your choice.

Main Ideas

1. Sharks possess a remarkable ability to locate their prey.
2. Sharks possess structural adaptations that enable them to survive in their chosen habitat.
3. Scientists are uncertain concerning the role of this structure or behavior in the life of the shark.

Details

- 1, 2 A. Sharks use their senses of smell, vision, and the "vibration sense" to locate their prey.
- 3 B. Researchers have found it unsafe to generalize from observations of a single shark or even a single species of shark.
- 1, 2 C. The nostrils which are located on the underside of the snout, have large folds of sensory tissue which are bathed by a current of water whether the shark is moving or not.
- 1 D. In experiments, dogfish sharks had no difficulty distinguishing a cheesecloth packet that contained crabmeat from identical packets containing stones.
- 1, 2 E. Plugging the nostrils of a shark affects its feeding activities.
- 1, 3 F. Frightened or distressed fish seem to give off some substance.
- 2 G. Movement of fluid in canals in the lateral line triggers nerve impulses.
- 2 H. While sharks generally do not have color vision, they do have high sensitivity to contrasts of light, shadow, and motion.
- 3 I. Nigrosene dye appears to be the most effective shark repellent to date.

PART II

Directions: The author mentions several experiments carried out by scientists in their study of the shark. In column A write the number(s) of the main idea(s) the experiment supports. In column B place the letter(s) of the detail(s) observed or discovered in these experiments.

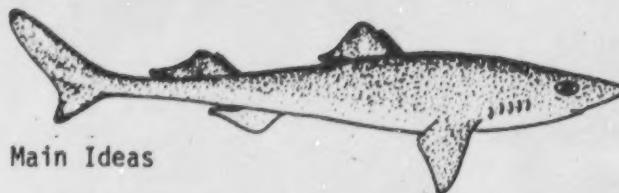
A B

- 2 A,D,E,F Ralph Sheldon at the Woods Hole Marine Laboratory was the first to demonstrate scientifically that the sense of smell is important in guiding sharks to a meal.
- 3 A,F,B Albert L. Tester of the University of Hawaii reported that black-tip and gray sharks showed a mild response to waters siphoned into their tank from another in which fish were swimming.
- 2 A,G,B George H. Parker of Harvard University found that a shark deprived of the senses of sight and hearing would continue to respond to a source of disturbance in the water as long as its lateralis system remained intact.
- 2 A,H,B Eugenie Clark of the Cape Haze Marine Laboratory tested the ability of an adult lemon shark to distinguish visually between targets of various shapes.

Directions: Now compare your answers with your group. Where there are differences, try to resolve them by reference to the selection.

THE BEHAVIOR OF SHARKS

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"THE BEHAVIOR OF SHARKS" - Main Ideas

PART I

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BIOLOGICAL FACTORS:

The Boney Fish - Osteichthyes

TEACHER BACKGROUND - Roll Them Bones and Fitting

"Roll Them Bones" and "Fitting" introduce your students to teleost or bony fishes. The introduction is brief and can be benefitted by supplementary materials from any of the works listed. The emphasis of these two activities lies on the adaptations that make bony fishes successful. Although important to their success, physiology and behavior have been largely ignored in these selections. An entertaining life history of the fishes may be found in "The Life Story of the Fish: His Manners and Morals" by Brian Curtis and cited at the end of the teacher background.

Supplement these activities with pictures and films. Since your students will have some familiarity with fish, your challenge will be to get them to view fish in a new manner. In this vein, bulletin board displays are effective, although overlooked, in most secondary classrooms.

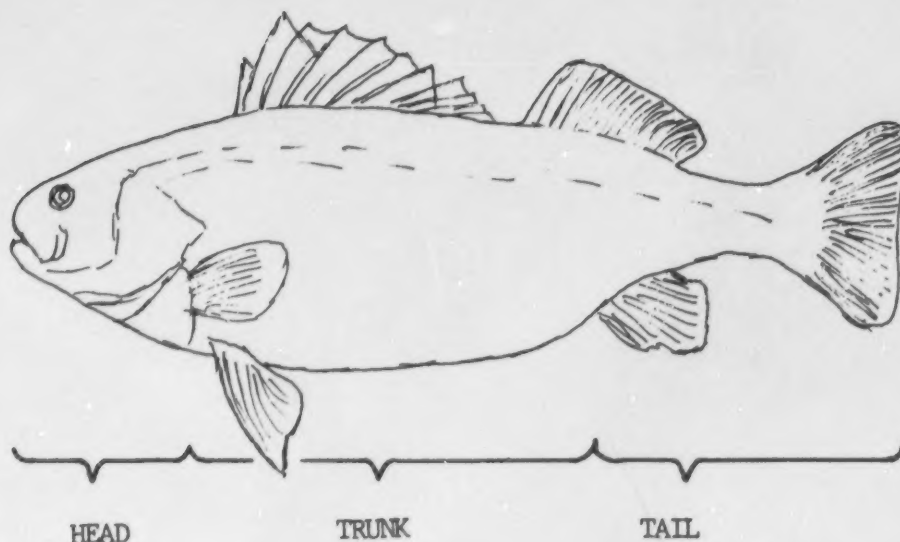
Duplicate the activity pages. One set is recommended per student. These activities may be assigned separately. They are best accomplished by individual students. You may find it worthwhile to have your students meet in small groups to discuss their observations before you discuss them with the class as a whole. In any case, be sure to allow some time for a discussion of the concepts involved in the activities and to provide answers for the text questions.

KEY

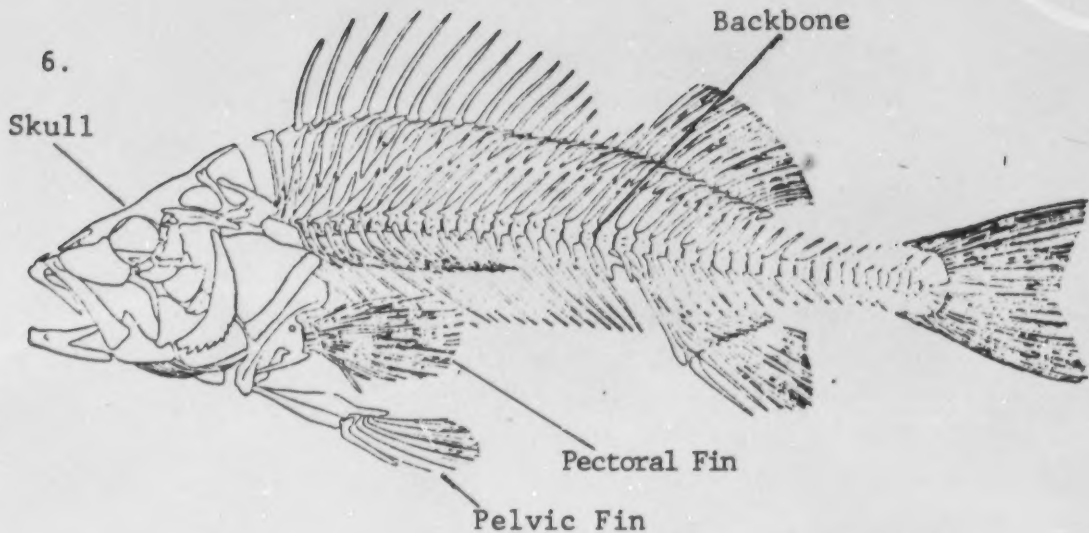
ROLL THEM BONES

1. Fish bodies are divided into three regions: head, trunk and tail. The tail section begins at the vent and includes the tail fin; the head begins at the nose and ends at the attachment of the pectoral fins; and, the trunk extends from the attachment of the pectoral fins to the vent.

The correct bracketing is shown on the drawing below:



2. The fish from which the scale was removed was in its seventh year.
3. The fish's mucus layer: acts as a lubricant; protects the fish from attack by fungus, bacteria and parasitic protozoa; and, regulates the movement of water into and out of the body cells.
4. The ability to change color allows the fish to resemble its background. The survival value of this camouflage lies in the fact that the fish becomes much more difficult for predators to detect.
5. Experiments will vary depending upon the experiences and creativity of your students. In general, they should involve directing light to the light underside to see if the light causes the underside to darken. Of passing interest are the observations of one experimenter who put flounders in a glass tank and directed constant streams of light onto the underside of the fish. The flounders did eventually produce colored pigment on the light underside. The fact that it took the poor fish over a year to do it leaves one uncertain whether the scientist proved his theory or merely showed what changes can be made in nature's arrangements when they are forcibly submitted to unnatural conditions.



Fitting - Answers will vary for these questions. The activity is designed to aid your students in making critical observations and in drawing conclusions from those observations. Bear in mind during your discussion of this activity that the answers are not as important as the process. In any event, the answers made from observations of a fish in hand are only hypotheses that must be tested by actual field observations.

The Petrale Sole

1. The uniform color tells us that the background upon which the fish is most often found is probably uniform in color. For instance, a sand or mud bottom. The olive brown color probably indicates a mud rather than a sand bottom.
2. The location of the mouth indicates that the sole probably feeds on or near the bottom.
3. The relatively small size of the mouth in proportion to the body size indicates that the sole eats small food items or at least small bites of food items.
4. The flattened shape, coupled with the unusual eye positioning indicates that the sole is a flat bottom dweller found lying on the bottom.

The Bay Pipefish

1. The color tells us that the pipefish is found against a non-uniform green background -- most likely vegetation of some description or another.
2. The very tiny mouth indicates a correspondingly small sized food. Most likely small plants and animals are sucked in through the tube shaped mouth.
3. The long thin, leaf-shaped pipefish would most likely be found among long thin leaves -- it's found in eel grass beds. Eelgrass blades and pipefish are very similar in appearance.

The Lantern Fish

1. The dark maroon or black color tells us that the fish most likely lives in the shadows where it is dark.
2. The low slung mouth gives us a hint that the lantern fish probably feeds on or near the bottom.
3. The lantern fish eats big food items in relation to its body size. It is most likely, then, a predator of some description feeding on relatively large animals.
4. The body is flattened ventrally, an indication that the lantern fish lives near or on the bottom.
5. The luminous spots indicate that the lantern fish spends at least a portion of its time in the dark. If we remember that the deepest parts of the oceans are in perpetual darkness, the observation fits well with a bottom dwelling, darkness inhabiting fish.

KEY WORDS

adaptations

anal

cartilage

caudal fin

chromatophores

coelacanth
 concentric
 countershade
 dehydrate
 dorsal
 fossil
 habitat
 ichthyologist
 gill
 lateral line
 mucus
 Osteichthyes
 parasite
 pectoral
 pelvic
 pigments
 protective coloration
 protozoa
 scales
 survival value
 trunk
 ventral
 vertebrates

Additional Reading:

Curtis, Brian. 1949. The Life Story of the Fish - His Manners and Morals. Dover Publications, Inc., New York.

Hart, J. L. 1973. Pacific Fishes of Canada. Bulletin 180. Fisheries Research Board of Canada, Ottawa.

Idyll, C. P. 1964. Abyss - The Deep Sea and the Creatures That Live In It. Thomas Y. Crowell Company, New York.

Otto, James H. and Albert Towle. 1977. Modern Biology. Holt, Rinehart and Winston. New York.

Wheeler, Alwyne. 1973. Fishes of the World - An Illustrated Dictionary. Macmillan Publishing Co., Inc. New York.

ROLL THEM BONES

In 1938, off the east coast of South Africa near the mouth of the small Chalumna River, a fisherman brought up a strange fish. The fish weighed nearly a hundred pounds and was about four feet long. The body was covered with large, circular scales. The strange fish found its way to the attention of the zoologist J.L.B. Smith. Smith could hardly believe his eyes. In front of him was a living member of a very ancient class of fishes which was believed to have disappeared some 70 million years ago! This living fossil, called a coelacanth (see-la-kanth), is perhaps the oldest "true fish". True fishes belong to the class Osteichthyes. Osteichthyes comes from the Greek words for "bony fishes". Unlike the sharks and rays and their relatives, true fishes have bony skeletons.



Coelacanth

Today, fish are the dominant vertebrates in both freshwater and marine environments. They live in depths over 20,000 feet and in shallows not deep enough to cover their dorsal fins. In nearly every habitat of the

sea, fish abound. What adaptations make bony fishes successful?

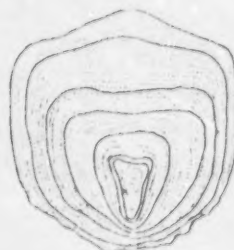
Aside from the bony skeleton that all of the true fish have, the bony fish share some other common features. They breathe through gills. They have fins. Most fishes have an outer covering of scales. Fish bodies are divided into three regions: head, trunk, and tail. The tail fin is attached to the tail region. As with most rules, there are some exceptions. A few fish breathe with lungs, and some have no recognizable fins.



1. Fish bodies are divided into three regions: head, trunk, and tail. The tail section begins at the vent and includes the tail fin; the head begins at the nose and ends at the attachment of the pectoral fins; and, the trunk extends from the attachment of the pectoral fins to the vent.

In the above drawing, place brackets around the three body parts and label each part.

Unlike your skin which is covered by several layers of dead and hardened cells, the fish's skin is alive to the very outermost covering. Because the outer cells of the fish are constantly exposed to water they do not need the protection from drying that our dead cell layers provide. The scales grow from pockets in the skin. They overlap like shingles on a roof. It is interesting to note that when the fish first comes out of its egg, it has no scales. A few fish, like the catfish, remain "naked" throughout life. Once the scales begin to form, they grow with the fish. As the fish grows bigger, the scales grow bigger. The number of scales, though, always stays the same. A young fish has the same number of scales as it will have when it is older. As the scales grow, concentric rings form on them. These rings grow closer together in the winter than they do in the summer. This observation is of more than casual interest since by looking at the scale rings, one can determine the age of a fish.



2. How old was the fish from which this scale was removed?

Fish skin contains glands that secrete mucus, or slime. The mucus seeps between the scales. This is what makes a fish slippery. The slime serves several purposes. In the first place, the slime acts as a lubricant that helps the body of the fish slide through the water. The fish can increase its speed while reducing the energy required to move through the water. Secondly, the slime protects the fish from attack by fungus, bacteria, and parasitic protozoa. Damage to the slime layer by handling etc. exposes living fish to parasites. The slime layer also plays an important role in regulating the movement of water into and out of the body cells. For ocean fish, this means that the slime layer helps keep them from losing water and dehydrating.

3. What are three roles the fish's mucus layer plays?

Fish have a variety and brilliance of color unequaled by any other group in the animal world. Many fish also have the ability to change color. To accomplish these color changes, fish have specialized skin cells called chromatophores (Greek; chromato (color) + phore (bearer) = color bearer). Chromatophores are little sac-like cells, shaped like many armed stars, which are scattered through

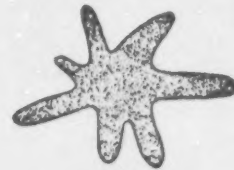
the skin in great numbers. Each contains colored pigments. The pigment can become practically invisible by withdrawing into the center of the cell, or it can expose its color in varying degrees by the extent to which the color spreads into the arms of the star.



pigment
contracted



partly
expanded



fully
expanded

4. How would the ability to change colors be of survival value to a fish?

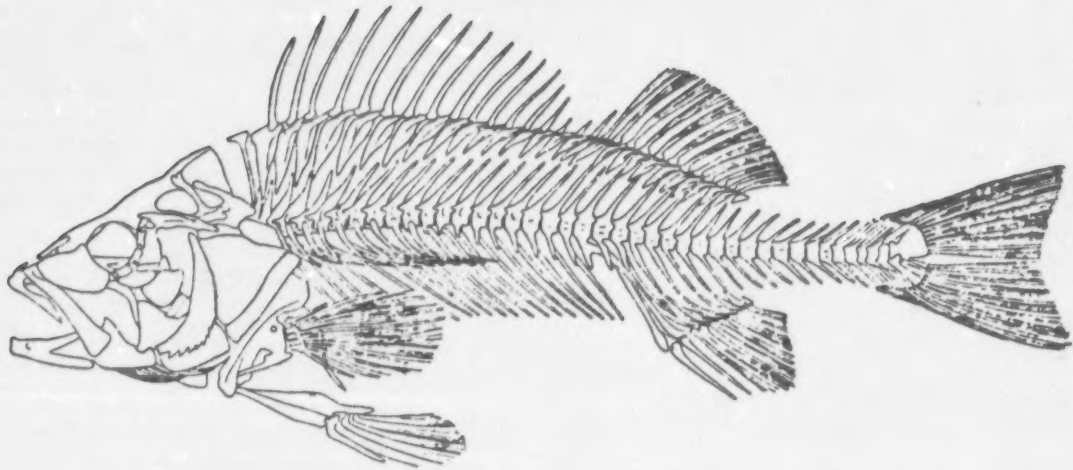
Many fish are countershaded. Countershading is a pattern of coloration in which the dorsal or back side of the fish is darker in color than the ventral or underside. It appears that the shading is a good example of protective coloration. The dark back is almost invisible to an enemy like a fish-hunting bird looking down from above into the dark water. To an enemy looking up from below, the light ventral or underside would be inconspicuous against the light coming from the surface.

5. Some ichthyologists (scientists who study fish) think that the countershading we see in fish is due to the effect of light on the fish's skin. In other words, the top of the fish "gets tan" while the bottom doesn't. Design and briefly describe an experiment that would provide evidence to support or refute this hypothesis.

It is the bony skeleton that separates "true fish" from their more primitive relatives, the sharks and rays. The essential elements of the fish framework include:

- a skull,
- a backbone made up of a series of vertebrae,
- two pairs of fins - the pectorals and the pelvics.

The fish framework also has one or more dorsal fins on the back, and one or more anal fins on the underside. These fins are made of bone or cartilage and are attached to the rest of the skeleton. It has a caudal or tail fin firmly attached to the end of the backbone. The bony skeleton provides a rigid framework that allows great variety in movement and provides protection for the internal organs.



6. Label the skull, backbone, pectoral fins and pelvic fins on the drawing above.

Using this basic framework and body design, fish have evolved an enormous variety of shapes and body styles. This variety has enabled fish to live successfully in almost all aquatic habitats. Dietary habits of fish also vary greatly. Some fish eat plants, others eat fish, and others eat a great variety of animal life.

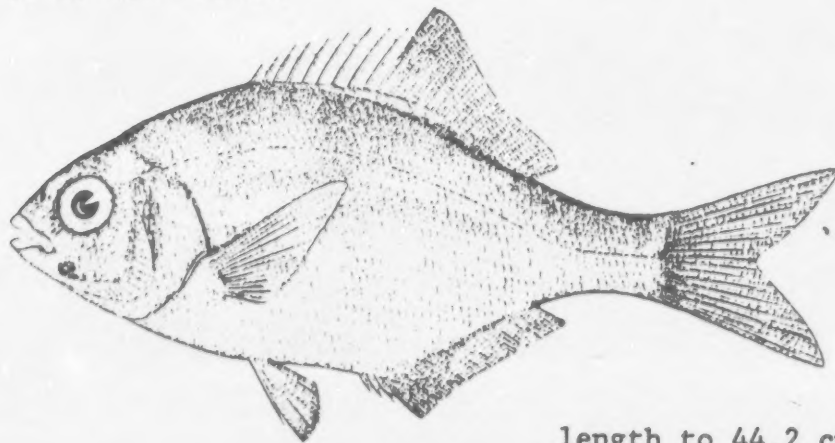
The following activity will give you an opportunity to examine some of the ways fish have adapted to their environment.

FITTING

A lot can be learned about a fish's way of life by simply looking at the fish. In this activity you will have a chance to "read a fish". As you look at the drawings, keep in mind these three concepts:

1. The color of a fish helps the fish to survive.
The color we observe can tell us something about the fish's way of life.
2. The shape and location of the mouth are adaptations for survival and can give us an insight into the way a fish lives.
3. The shape of the body is also an adaptation that helps the fish survive. The body shape often tells us where and how a fish lives.

Let's look at a Pile Perch (scientific name Phacochilus vacca) and see what we can learn.



length to 44.2 cm.
(17.4 inches)

Color: Dark gray or brown on back. Silvery sides and belly with dark bars on side.

What does the color tell us? The countershading gives us an indication that the pile perch is probably a mid-water fish. How? The dark color above helps it hide from attack from above while the light underside helps it hide from attack from below. The dark vertical bars give us a hint that we might expect to see this fish against backgrounds with strong vertical elements (like piers and pilings!)

What does the mouth tell us? The relatively little mouth would be good for eating small bites of plants and small animals. The location of the mouth tells us the perch probably doesn't spend much time feeding on the bottom or on the top near the surface of the water. Since its mouth is in the middle, it probably feeds at the middle depths.

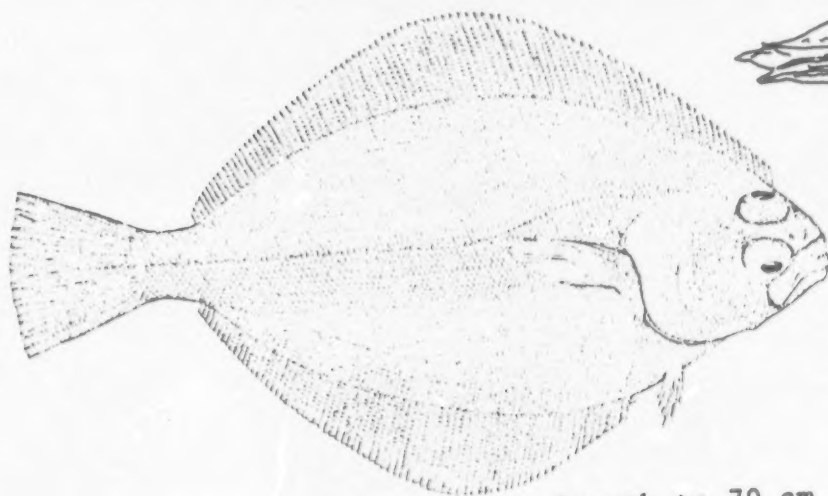
What does the shape tell us? The bullet shape gives us a hint that the perch is probably a relatively fast swimmer. (The well developed caudal (tail) fin also hints at this swimming ability). The perch is also a thin fish (something you can't tell from the drawing). Thin fish are good at hiding by turning sideways.

Can we learn anything else? The well developed eye may be an indication that vision plays an important role in the perch's survival. The prominent lateral line, which senses vibrations, probably indicates that the pile perch is very sensitive to disturbances in the water.

Are we right? While we can read quite a bit about a fish's life story from its body, we have to be careful to check our theories with real life observations. For example, some fish have very big eyes but poor vision. In the case of the pile perch, we can go to our favorite local dock and check our guesses. The pile perch is most often found near rock out croppings or pilings at the mid-water depth. It feeds in the mid water zone and eats small crabs and other animals. It will rapidly dart away if you drop a small pebble into the water (a good swimmer with a good lateral line!).

Try your powers of observation with the following fish:

The Petrale Sole (Eopsetta jordani) is a uniform olive brown on the eyed side. The blind side is white. The sketch to the right of the drawing shows how the fish is oriented while swimming.

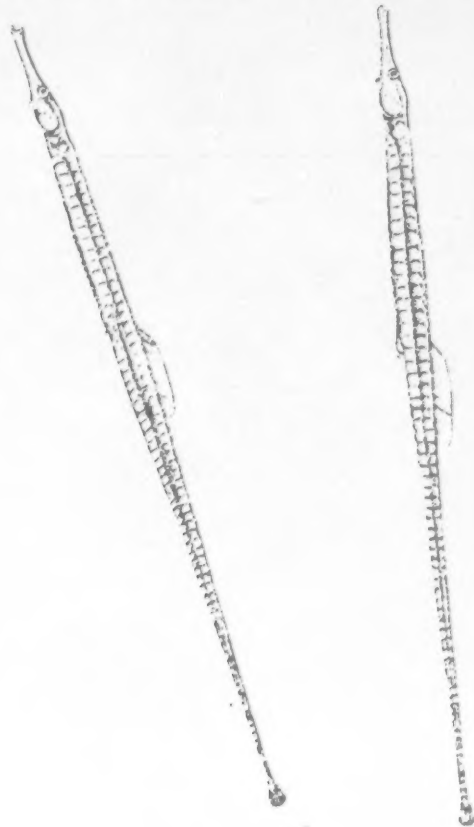


frontal view

length to 70 cm.
(27.5 inches)

1. What does the color tell us about the background on which we would most likely find the Petrale Sole ?
2. What does the location of the mouth tell us about where the sole feeds?
3. What does the size of the mouth tell us about what the sole eats?
4. What does the body shape tell us about where you would most likely find this fish?

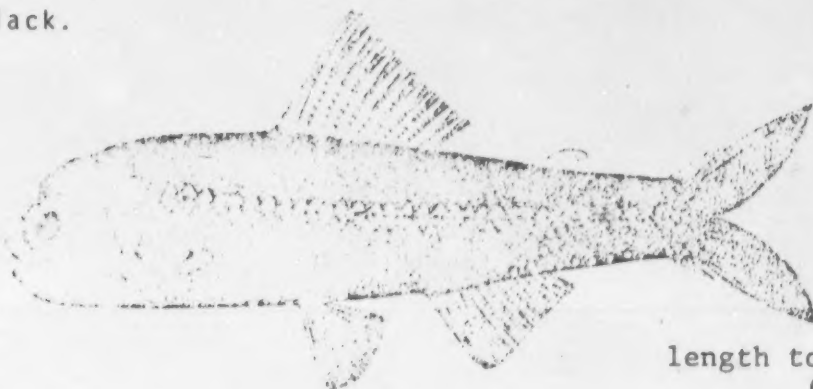
The Bay Pipefish (Syngnathus griseolineatus) is a pale olive green with narrow horizontal gray lines. It is shown in its most common orientation to the bottom.



length to 33 cm.
(13 inches)

1. What does the color tell us about the background which we would most likely find the bay pipefish?
2. What does the size of the mouth tell us about what the pipefish eats?
3. What does the body shape tell us about where one would most likely find the bay pipefish?

The Lanternfish (Aethoprora effulgens) is dark maroon or black.



length to 15 cm.
(6 inches)

1. What does the color tell us about where the lantern fish lives?
2. What does the location of the mouth tell us about where the lantern fish feeds?
3. What does the size of the mouth tell us about what the lantern fish eats?
4. What does the body shape tell us about where the lantern fish lives?
5. The spots near the lateral line produce light. Does this observation agree with your answers in numbers 1 and 4 above? Explain.

Hey! This is pretty easy..... For your enjoyment
you might try the fish below:



length to 33.6 cm.
(13.25 inches)

The Shortjaw Eelpout (Lycenchelys jordani) is brownish olive.



length to 76 cm.
(30 inches)

The Roughscale Rattail (Coryphaenoides acrolepis)
is brown to black dorsally, paler below.

TEACHER BACKGROUND - How Old Are You?

Determining the age of fish by counting annual marks (annuli) is a standard technique used by biologists and fisheries personnel. The theory is simple and with a little patience the actual practice can be mastered by your students. You will find that there is a wide variety in the ease with which fish of different species can be aged. Your students will tend to become frustrated if you select the "wrong" fish. For this reason a list of suitable fish follows. You can easily determine if other fish are suitable by removing a few scales and observing them yourself.

Easily Aged Fish

- members of the perch family (Percidae)
- members of the bass family (Serranidae)
- members of the sunfish family (Centrarchidae)
- anchovy
- striped bass
- flounder

It is often difficult to distinguish between true annuli and other markings on a fish scale. These difficulties tend to be reduced by practice. Encourage your students to look at several different scales. True annuli parallel the scale margin and reflect the crowding of the circuli that occurs just prior to the resumption of growth. As you perform this activity remind your students that they are obtaining "best guess" information. There is really no way for them to determine if their estimates of age are the actual age of the fish. Be aware of the potential frustration brought on by this type of "real-life" investigation.

If the fish scales obtained are large and thick, your students may find it easier to mount them between two slides rather than using a slide and coverslip. Alternate methods of examining the scales do exist. For a nice demonstration, place the scales between two thin layers of clear plastic. The sandwiched scales are then mounted in a 35 mm photographic slide frame. The scale can then be

projected on a screen so that the entire class can view the scale and count the annuli. Other fisheries biologists prefer to examine the impressions of fish scales left in plastic sheets rather than the fish scales themselves. This method involves the use of a fish scale press.

The annual rings found in other hard structures in fish may be used to age fish. The otoliths or ear stones are widely used as are vertebrae. As an aside, many molluscs also reveal annual growth rings on their shell. Mussels, oysters and clams provide suitable subjects. Molluscs, however, are more likely to show the effects of environmental changes. In addition, the shells are sometimes quickly eroded away which makes counting very difficult.

As you perform the activity, emphasize that the technique is a tool used to obtain information helpful in the management of fisheries resource. Age data is important in making resource decisions. If such was not the case, fish scale annuli would be little more than an interesting curiosity.

Duplicate the activity pages. One set is recommended per student. Consider demonstrating the technique to your class prior to their performing it. You may wish to project a scale slide as detailed above. Circulate through the lab as the activity occurs. Since some scales are more readily aged than others, encourage your students to observe many different slides. Upon completion, plan to allow some time for a discussion of the techniques and to provide correct answers to the text and "Analysis and Interpretation" questions.

KEY

Text Questions

1. Each annuli represents the end of the growth for a given year. The relationship of one annulus per one year allows biologists to determine a fish's age by simply counting the annuli.

2.

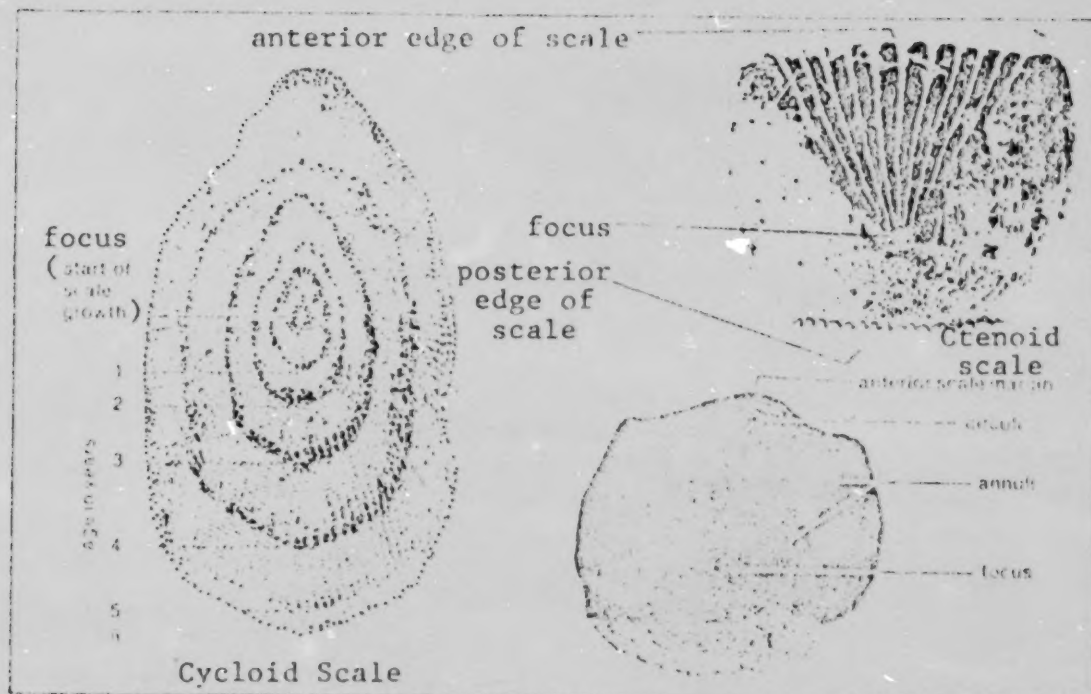


Since there are 7 annuli, the best estimate for the fish's age is 7 years.

3.



4.



5. The fish from which the cycloid scale was obtained was in its sixth year. (see the labeled drawing in number 4).

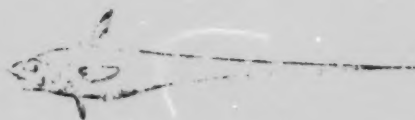
Analysis and Interpretation

1. - 7. Answer depends upon experimental observations.
8. It is important to age more than one fish scale for several reasons. The primary reason is that a larger sample size allows us to put more faith in our results. Fish also lose scales. As the scale regrows, all of the annuli are not replaced. Damaged scales are also difficult to read and likely to give erroneous results. Sampling several scales can reduce the chance of error from these sources.
- 9.a. False annuli would cause the researcher to over-estimate the age of the fish. The fish would actually be younger than the age in years which equals the number of annuli present.
- b. Sampling several fish of the same size and species can help reduce errors due to false annuli by providing a relationship between the length and age. If a sampled fish differs radically from what is expected one is alerted to suspect false annuli, replaced scales or some similar anomaly.
- 10.a. While the results depend upon the experimental observations, in general, the relationship exists that the longer the fish, the greater the number of annuli.
- b. The graph will depend upon experimental results. Regardless of specific data plotted, certain things should be present on the graph: a title, labels for vertical and horizontal axes, a curve connecting data points.
- c. An age-length graph lets a field biologist estimate the age of the fish by moving up the axis above the observed length to the point of intersection with the curve. From the point of intersection, a line is drawn across to the age axis. Read the age which corresponds to the length. This explanation is more complex than the actual operation.
- d. Age information gathered from scales can be used to establish an age length graph. The size of fish at an immature age can be used to establish regulations limiting the size of the herring captured.

KEY WORDS

age-length graph
annulus
anterior
capillary action
circulus
ctenoid
cycloid
dorsal
focus
lateral line
perpetuate
posterior
scales
species
sustained yield

HOW OLD ARE YOU?



"How old are you?" a strange question to ask a fish. Why would you care? Age and growth rate information is of vital importance for the proper management of fishery resources. For example, fishers should return any immature fish to the water. This return gives each individual fish a chance to reproduce itself at least once before it goes to market or table. To obtain a sustained yield, it is necessary to permit the young to escape from catches. The young fish can then mature in order to perpetuate the species. The evaluation and conservation of a fishery depends upon the ability to determine the age of the fishes.

So, to avoid harming the population by taking young individuals, we need to know the age of the fish we're catching. How can you tell the age of a fish? Most fish are born without scales. At some predetermined time the scales form. At this time all of the scales the fish will have are formed. In other words while the fish and its scales may grow in size, the number of scales remains the same. Growth begins at the focus, a point near the center of scale. As growth proceeds, fine ridges called circuli are laid down in a circular pattern around the focus. Many circuli are added each year.

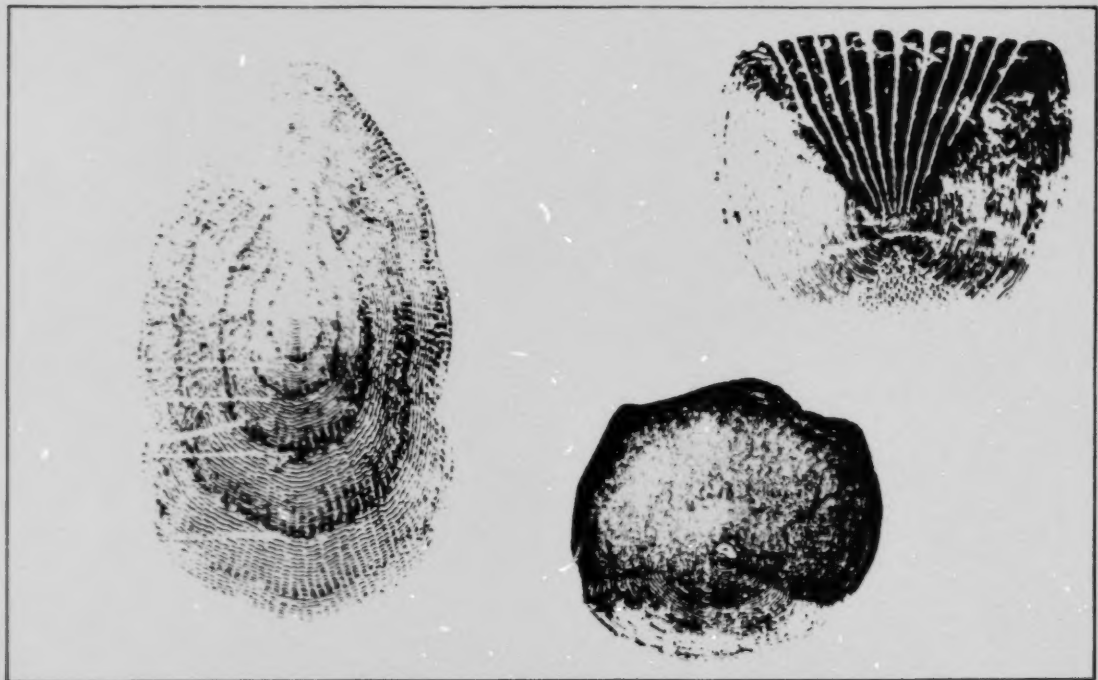
The circuli are widely spaced in warm seasons when growth is rapid and closely spaced in cold seasons when growth is slow. Thus, one year's growth is revealed as a series of widely spaced spring and summer circuli followed by a series of closely spaced fall and winter circuli. This pattern is repeated each year. The outer edge of a series of closely spaced circuli represents the end of the growth that year. This closely spaced end region is called the annulus. The age of the fish is determined by counting the number of annuli (plural or annulus) or year marks.

1. How can the number of annuli be used to determine a fish's age?

Sounds easy, right? Try your hand on the picture of the scale below. (Hint: the outer edges of the circuli are so close together they form dark lines.)

2. How old was the fish from which this scale was taken?
3. Label the focus, one circulus, and one annulus.

Among the bony fish there are two major types of scales. The scales on perch, salmon, and many other fish have tiny spines on the exposed posterior portion. (The posterior portion is the portion away from the head.) These spined scales are called ctenoid scales. Some soft rayed fish have scales with no spines. These "spineless" scales are called cycloid scales. The pictures below show these two types of scales.



4. Label the cycloid scale and the ctenoid scale; label the posterior and anterior edges of the ctenoid scale; and label the focus on each scale.
5. How old was the fish from which the cycloid scale came?

Are you ready? Use the procedure below to determine the age of your fish....

Materials:

compound microscope

forceps

microscope slides

cover slip

balsam mounting medium (optional)

alizerin stain

fish (a series of different sized fish of the same species
or is ideal)

fish heads of a variety of fish (eg. perch, bass, sunfish, etc.)

Procedure:

1. Obtain a fish or fish head. Record the common and scientific names _____.
2. If the entire fish is available, remove the scale from the middle of the body under the anterior part of the dorsal fin and above the lateral line. If only a fish head is available, use scales from the dorsal and ventral surface. Use forceps to gently remove at least five scales.
3. Rinse the scales thoroughly with tap water.
4. Prepare a wet mount by placing each scale on a glass slide, adding a drop of tap water and covering with a coverslip. If you prefer, you may make permanent slides by carefully blotting the scales dry and placing each scale in a drop of balsam mounting medium on a slide and covering with a coverslip.
5. Examine the slides under the low power of your microscope. Adjust your light source to get the maximum contrast between the growth rings and the background. If you find the growth rings difficult to distinguish, place a drop of alizerin stain on the edge of the coverslip and allow capillary action to draw the stain beneath the slip.

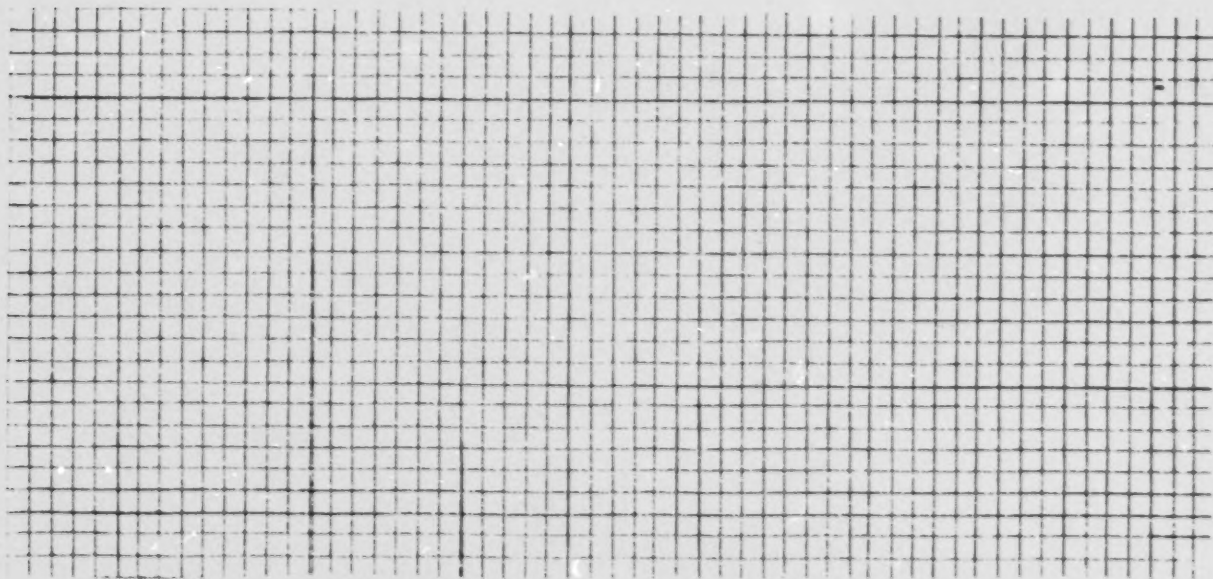
6. In the space below, diagram a scale as you see it through the microscope. Label those features which you can identify.

Analysis and Interpretation

1. Is the scale cycloid or ctenoid? _____
2. If you removed scales from the dorsal and ventral portions of the head, were both scales of the same type, cycloid or ctenoid? _____
3. How many annuli are present? scale 1: _____
scale 2: _____ scale 3: _____
scale 4: _____ scale 5: _____
4. Can the numbers of annuli be easily determined? _____
5. For the fish you sampled, what is the average number of annuli you observed? _____
6. How old is your fish? _____
7. Why is it important to age more than one scale?

8. Changes in oxygen, temperature, and food supply as well as rough handling by people can result in rings that look like annuli.
- How would these false annuli affect age estimates?
 - How could sampling several fish of the same size and species help reduce errors due to false annuli?
9. If your class is using different sized specimens of a single species, record your fish length and the number of annuli on the board for class analysis.
- What is the relationship between length of fish and number of annuli?

 - Use the grid below to plot age (number of annuli) vs. length.



- c. How could an age-length graph be used by field biologists to quickly estimate the age of a fish?

- d. The herring is locally in danger of being overfished. Fisheries biologists want to prohibit fishers from netting immature fish before they can reproduce. How might information gathered from fish scales be useful in establishing a regulation to protect the herring?

BIOLOGICAL FACTORS:

Salmon - A Special Case

TEACHER BACKGROUND - The Salmon Story and Cycles

In the Pacific Northwest salmon are synonymous with controversy. These fish support an important commercial fishery and a significant sport fishery. Arguments between commercial fishers and sport fishers have flaired for years. Recently, new controversy has surfaced regarding Indian vs. non-Indian fishing rights. At issue in these arguments is the allotment of the multimillion dollar salmon resource. In the eyes of many biologists, the survival of the salmon is also at issue. In spite of the fact that destruction of the salmon benefits no one, many actions proposed or underway threaten the existence of the species. Subsequent activities deal with many of the specific issues of these controversies. "The Salmon Story" and "Cycles" provide some of the biological background information necessary to understanding the salmon.

Complete life histories of the salmon species and an in-depth treatment of the controversies surrounding these fish are beyond the scope of this guide. For additional information, please consult the following publications:

Barsh, Russel L. 1977. The Washington Fishing Rights Controversy: An Economic Critique. University of Washington, Graduate School of Business Administration; Seattle. 61 pages.

_____. 1978. Understanding Indian Treaties as Law. The State Superintendent of Public Instruction; Olympia, Washington. 74 pages.

Dyckman, Claire and Stan Garrod. 1977. Small Streams and Salmonid: A Handbook for Water Quality Studies. United Nations Educational, Scientific and Cultural Organization; Paris. 222 pages.

Netboy, Anthony. 1958. Salmon of the Pacific Northwest. Binforde and Mort, Publishers; Portland, Oregon. 122 pages.

_____. 1973. The Salmon - Their Fight for Survival. Houghton Mifflin Company; Boston. 613 pages.

"Cycles" is an exercise in critical graphics interpretation. The information presented in two life cycle charts is used to provide answers to text questions.

Duplicate the text pages. One set is recommended per student. These activities are best completed by individual students. They may be assigned as homework or completed as "in class" activities. Plan to provide the correct answers to the text questions as you discuss the materials. Alternative approaches are, of course, available. You may elect to have your students meet in small groups to discuss their answers to "Cycles" prior to your class discussion. As always, use the approach that works best with your particular class.

KEY

The Salmon Story

1. Answers will vary but the best guess is that "ebb and flow" refer to movement of the ice sheets. This question is designed to encourage students to look critically at the materials they read.
2. The major difference mentioned between members of the genus Onchorhynchus and members of the genera Salmo and Salvelinus is that all species of Onchorhynchus die very soon after reaching maturity.
3. "Anadromous" is a term referring to fish that spend most of their life at sea, then move into fresh-water to spawn. Salmon are the classic example of anadromous fish.
4. While the answers will vary somewhat, a "stream enhancement program" is an action undertaken to cause changes in a stream that will benefit one or more species by altering the habitat of the stream to provide those things required by the target species for survival.
5. Most of your students will say that the salmon begins to resemble a fish at the alevin stage. Some may not see the resemblance until the fry stage.

6. The major difficulty that has restricted our knowledge has been the inability to follow the fish in the ocean. It has also been largely impossible to identify the point of origin of the fish observed. Recent improvements in sampling and tagging fish are providing information about what the salmon does during its stay in the ocean.
7. Trollers would be more likely to catch Coho and Chinook salmon since these two species feed on fish and other prey up to the size of a herring. They would be less likely to catch Chum, Pink and Sockeye since these species are plankton feeders. These three species are most often caught using net gear.
8. A run in which more than two adults return and successfully spawn for each pair that spawned in a previous generation will increase in size. It is also possible for a run to decrease in size if fewer than two adults return and successfully spawn for each pair that spawned in a previous generation.
9. Many things can cause panic in homing salmon including: the smell of predators, dogs, barriers, etc. This question is included as a preview for the material which occurs in the next paragraph. It is designed to help your students learn to anticipate.
10. The most obvious difference is the lack of teeth in the sockeye. The chinook also has a slightly larger and more upturned mouth better designed for attacking and holding prey.
11. As the salmon moves upstream, many changes take place. These changes are designed to enable the salmon to spawn or reproduce more successfully.
12. "Redd building" is defined as nest construction in the first sentence of the paragraph. In this case the context clue that defines an unfamiliar word follows the word.

13. The recently excavated redds downstream are covered with the rocks and silt moved by salmon upstream. It has been estimated that a significant percentage of salmon eggs are destroyed by the redd building activities of other salmon. You might relate this high mortality to the large number of eggs laid.
14. The salmon eggs can only be fertilized for a very short time (about one and a half minutes). It is an advantage to have the sperm begin swimming immediately upon contact with the water so that they have the highest probability of coming into contact with an egg before the egg surface hardens.
15. Since salmon die after reproducing, the loss of all the eggs in the two redds means that there will be a loss of salmon in these areas in the future. The destruction of the redds will cause a destruction of a particular year class for each of the species involved. For example, pink salmon have a two-year cycle. In the year following the destruction, the salmon currently at sea will arrive. The second year following, there will be no pink salmon in the areas of the redd destruction. This question points out the fact that destruction of the breeding grounds does not show up immediately. This fact often makes it difficult to establish the causes of reduced salmon production.
16. The young fish are called fry. This information is available in the chart of salmon development provided earlier in the text.
17. Since the different species of salmon have different life histories, only a generalized life cycle is possible. The critical information that should be present includes: eggs are laid in the gravel redds; eggs and alevins develop in the gravel; the fish emerge as fry; at some point the fish migrate downstream to the ocean; the fish develop in the ocean; the adults migrate back upstream to the area of their "birth"; the female adults lay the eggs which are fertilized by the males; the cycle begins again. In your discussions, stress the anadromous nature of the life cycle.

Cycles

1. The pink salmon is first to deposit eggs at the spawning grounds in the fall of the year.
2. As they dig their redds ("nests"), female coho salmon are more likely to disturb the eggs of pink salmon which were laid earlier in the season.
3. Alevin of both species obtain energy from the material stored in the yolk sack as they live in the stream gravels from January to April.
4. Pink salmon move downstream as soon as they emerge as fry. Coho salmon, on the other hand, remain in fresh water for from one to two years.
5. Both pink salmon and coho salmon mature while they are in the ocean.
6. Pink salmon have a highly regular two year cycle while the coho salmon have a life cycle that can be from two to four years in length.
7. Salmon gain most of their body weight during the period they spend feeding in the oceans. Since they spend more time in the oceans we might expect that coho salmon would be larger than pink salmon.
8. Logging and road building operations can cause fine silt to be deposited in salmon streams. The silt fills the small spaces between the gravels in the stream bed. Poor logging and/or road building techniques would have the most effect on salmon in the egg and alevin stages.

Silting is critical at these two stages because
silt fills the small spaces and smothers the
eggs and alevins.

9. Knowledge of the life cycle of a fish is important to people who make decisions regarding the number of fish available for catching (harvest). What are two other kinds of information these resource managers would find useful in making wise decisions?
 - a. food habits; predators; diseases; habitat requirements;
 - b. population numbers, etc. (Any two will suffice to start a discussion on salmon management.)
10. Arrange the following stages in the life history of the salmon in their proper sequence by placing numbers in the blanks to the left of the stage. The first stage should be labeled number one and so on. The first stage is done for you.

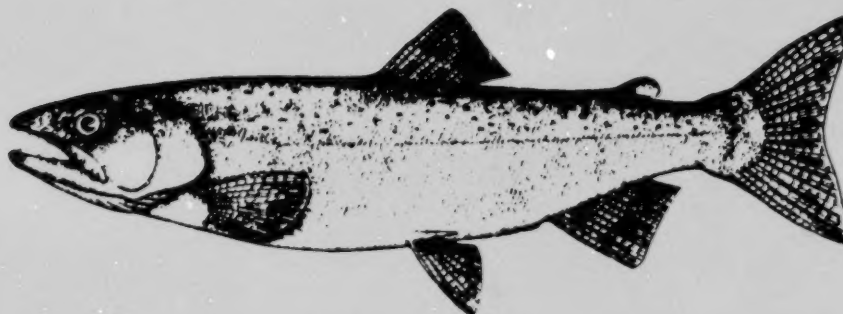
- | | |
|----------|---|
| <u>3</u> | egg develop in the stream gravel |
| <u>5</u> | fry emerge |
| <u>4</u> | alevin in stream gravel |
| <u>7</u> | fish mature in oceans |
| <u>6</u> | fry or young fish swim downstream |
| <u>2</u> | eggs are laid |
| <u>8</u> | adult fish begin upstream migration to spawning grounds |
| <u>1</u> | redds are dug |

KEY WORDS

alevin
anadromous
carcasses
courtship
decimation
eggs
embryo
fry
genus
imprinting
life cycle
migration
milt
Miocene
natal
oesophagus
olfactory
Oncorhynchus
Pacific Northwest
plankton
Pleistocene
predators
redd
Salmo
salmon
Salmonidae
Salvelinus
smolts
stimuli
stream enhancement program

THE SALMON STORY

Prior to this century the thousands of creeks and rivers in the Pacific Northwest teemed with fish, most of which were members of the same family - - the salmon family. The detrimental side effects of man's developing technology and exploitation of natural resources are readily visible in the decimation of stocks in many rivers. Understanding the conditions necessary for optimum survival of the Pacific Salmon through the various stages of their lives enables more effective stream enhancement programs. Maybe some day we will again see the rivers turn red.



COHO SALMON

Oncorhynchus kisutch

Evolution of Salmonids

The SALMONIDAE have evolved in cold oxygen-rich waters of the Northern Hemisphere, sharing a common heritage dating to the Miocene. They still retain many primitive

features, such as soft branched rays in the fins rather than firm spines and pelvic fins that are situated far back on the body. Internally, salmonids have a primitive type of air bladder connected with the oesophagus by an open pneumatic duct. The present distribution and anadromous behavior of the salmonids and trouts are thought to be a result of the ebb and flow of the Pleistocene.

1. How's that for a confusing sentence? Maybe Webster's definition for the word Pleistocene will help us. Pleistocene is defined as a time period "characterized by the spreading and recession of continental ice sheets...." What do you suppose the author was referring to when she wrote: "the ebb and flow of the Pleistocene"?

At this time, salmonids in the Pacific became separated from parent stock in the Atlantic. In isolation each responded to differing environmental pressures and evolved along different lines, resulting in the kinds of fish we have today. The Atlantic salmon and true trout form the genus *SALMO*; chars and brook trout, the genus *SALVELINUS*; and six species of Pacific salmon, the genus *ONCORHYNCHUS*. All species of *Oncorhynchus* die very soon after reaching maturity due to physiological changes taking place within their bodies. All species of

Salmo and Salvelinus do not go through this hormonal imbalance and therefore survive maturity, enabling them to spawn more than once in their lifetime.

2. What is a major way in which the members of the genus Oncorhynchus differ from the members of the genus Salmo and the genus Salvelinus?



ATLANTIC SALMON

Salmo salar

Migrations

Movement in and out of the natal (birth) streams is a facet in the lives of all three genera. Migrations take place with regularity and at set times of years for the purpose of feeding or for spawning. This behavior is common in many fishes. Catadromous and anadromous are two classical types of migration. Catadromous movements are from fresh-water to the ocean. The fresh-water eels

of the east coast feed in lakes and rivers, then move to sea to spawn. The opposite, anadromous migration, carried out by the salmonids and Pacific Lamprey, spending most of their lives at sea, moving into fresh water to spawn. Potanadromous refers to fish that remain in fresh water. This includes Cut-throat Trout, Brook Trout, Rainbow Trout and land-locked salmon such as the Kokanee. Rainbow Trout that have developed the anadromous pattern are known as steelhead. Coastal Cut-throat Trout and Dolly Varden commonly move between fresh water and salt for the dual purposes of spawning and feeding.

3. What is meant by the term anadromous?

At any time of the year in coastal waters and streams of the Pacific Northwest you will find: Sockeye, Pink, Chinook, Chum, Steelhead, Cut-throat Trout, Dolly Varden, Rainbow Trout and Kokanee at varying stages of maturity. All species must be considered in any stream enhancement program, as each have unique habitat requirements for their survival and beneficial changes for one species may be detrimental to another.

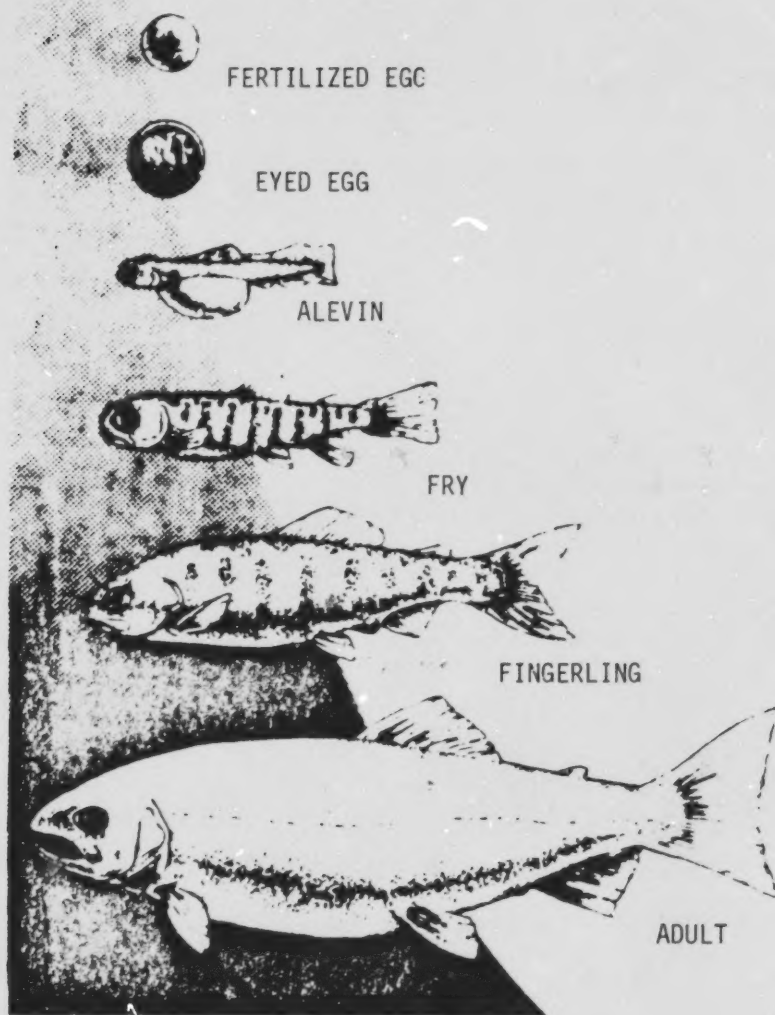
4. Use the context of the rest of the sentence to define what is meant by the phrase "stream enhancement program"?

All these fish are spectacular in their beauty and grace. The odyssey of their life cycle can be a phenomena of fantastic feats, stamina and endurance. Our lives are richer because we can observe, begin to understand and appreciate their existence.

It is possible to describe a typical life cycle for the salmon with the understanding that there will be variation depending upon the species concerned.

PACIFIC SALMON DEVELOPMENT

*Adapted from a Washington State
Department of Fisheries Bulletin*



5. At which stage in development does the Pacific Salmon begin to resemble a fish?

The mystery of the salmon's life at sea is slowly unravelling. As ocean currents in the Northern Pacific flow counter-clockwise along our continental shelf, the direction is northward towards Alaska and the Aleutian Islands. This mighty ocean river teems with life, from microscopic plants and organisms to fish and mammals. What better place to grow for the billions of young salmon than here?

6. Knowledge about the salmon's life history while in the oceans has been difficult to obtain. What is one difficulty that has restricted our knowledge?

Feeding migrations are governed by water temperatures which tend to move the fish northward with the rising temperatures of spring and summer, then southward in the cold of winter. The number of circuits completed varies with the salmon species, with individuals within the species and with their destined life spans. The salmon swim an average of 12 miles per day, feeding near the ocean surface at dawn and dusk, then moving to the deeper depths during the day.

Feeding while swimming, the Chum, Pink and Sockeye

open their mouths wide, scooping in myriads of plankton. The gill rakers, projections from the gill skeleton, strain food from the water, which is then swallowed into the stomach, where with the aid of pyloric caeca, digestion and absorption take place. The Coho and Chinook, with their better developed teeth, are able to capture larger prey, up to the size of herring. The varying number and structure of gill rakers and pyloric caeca are a means of identifying salmon.

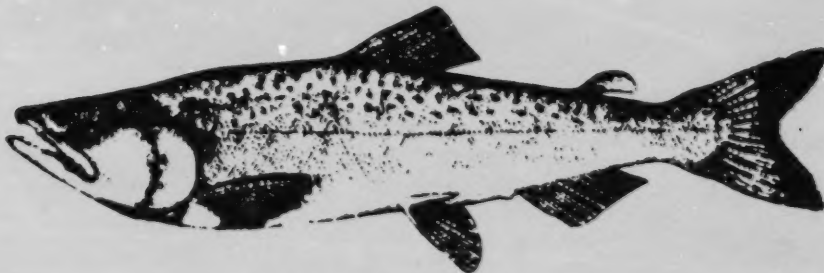
7. Trollers fish for salmon on the open ocean. Essentially, they use hooked lures that are thought to resemble bait. Which of the five salmon species mentioned above would trollers most likely catch? Why?

Marine life is hazardous, as numerous predators, such as larger fish, seals and whales take a heavy toll of the juveniles. Studies have shown that the number of salmon that return as adults to spawn is low, approximately one to ten percent of the fry. If a run is to be maintained, at least two adults must return and successfully spawn for each pair that spawned in a previous generation.

8. What will happen to the size of a run in which more than two adults return and successfully spawn for each pair that spawned in a previous generation?

All individuals of a species enter puberty at the same age, with the exception of precocious males (jacks) who are a year younger. With the onset of maturity, the salmon become a precise biological clock, moving swiftly, averaging 30 to 40 miles per day as the homeward migration begins. Great numbers of different species can be seen swimming together as they race for home.

How do salmonids perform these navigational feats when their brain is no longer than two to three centimeters? It is known that they respond to many external stimuli such as thermoclines (differences in temperature), polarized light, electro-magnetic cues from ocean currents and detection of varying salinities in the water. As more information is gathered, we may eventually understand how salmon correlate the varying stimuli to accomplish their migration. We do know that the fish return to an exact stream and/or tributary of a large river system such as the Fraser or Columbia. Our information about migration becomes clearer as the salmon near their parent streams, for now the olfactory sense (sense of smell) becomes a navigational aid.



CHINOOK SALMON •

Oncorhynchus tshawytscha

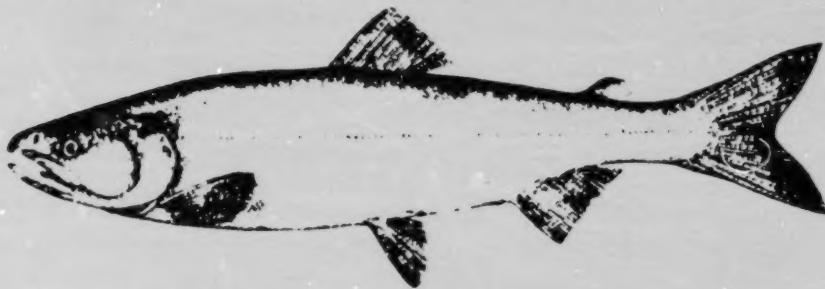
Spawning

As the fish head upriver, water flowing over the nares (nose openings) carries the scent of the natal stream. Each stream has a unique chemical composition and the salmon with their highly developed olfactory lobes are able to detect their home scent in minute concentrations. They now respond to the imprinting which took place when they were fry and head for the more concentrated source of smell. This is a strong but easily disrupted response. Anything that causes panic will block the response, resulting in the fish either milling around or actively swimming downstream until the panic subsides.

9. "Imprinting" in this case means that the particular smell of the stream is fixed in the fish's memory. The fish will always recall the odor of its "own" stream. What are two things that might cause panic in a homing salmon?

Their journey upstream is not easy. Floods, natural dams and low water will all have an effect upon the stream smell. To compound their problems, just a slight smell of any predator will immediately trigger the panic reaction. Smell of animals not normally considered predators also causes panic; this is especially true of dogs and man. A Pekingese standing with his paws in the water will spook salmon 100 yards (30 meters) downstream.

When the salmon arrive at the river mouth, they are in varying stages of maturation. Sexual development has been in progress since the beginning of the summer. Those fish that travel hundreds of miles inland enter early and mature enroute. Fish that spawn near salt water are generally sexually mature prior to entry.



SOCKEYE SALMON

Oncorhynchus nerka

10. How does the mouth of the Sockeye Salmon differ from that of the Chinook Salmon? How might these differences be related to differences in diet?

Movement is usually during the day, more often in early morning and late afternoon. The formation of glucose from amino acids and lipids provides the added carbohydrates necessary for the persistent movement and muscular activity of the migrating salmon. As each difficult stretch of river is traveled, the salmon then

rest in quiet pools, hiding in the depths from predators such as bear, otter, mink and man. The fish travel rapidly to the precise tributary and gravel spawning grounds from which they emerged as fry. These areas are in shallow, swiftly moving water with river rock of "golf ball" size.

As the salmon adjust to a fresh water environment, many physiological changes take place. Reproduction becomes the major body function. The fish no longer feed, but exist on fats stored both between and in the fibres of the muscle tissues. The skin thickens and scales are re-absorbed to help meet nutritional deficiencies during this period of fasting. The kidneys and other excretory systems, such as the gills and skin must regulate the body's rapidly changing water and salt balances. Each species of salmon develop the distinctive colors and features of sexual maturity. The colors, due to concentrated carotenoids in the skin, are important for the spawning behavior. Varying degrees of red trigger the courtship patterns and inter-specific responses between individual salmon. Males form the well known hooked snout. The females externally show less dramatic change, although their bodies are noticeably swollen as thousands of developed eggs are released into the body cavity.

11. As the salmon moves upstream, many changes take place. These changes are designed to enable the salmon to _____ more successfully.



CHUM SALMON
Oncorhynchus keta



PINK SALMON
Oncorhynchus gorbuscha

Courtship behavior is an important phase leading to the spawning climax. Varying with the species, it may begin upon entering the river or not take place until actually on the spawning grounds. The male nudges the female with his nose, quivers close beside her and sometimes simulates redd building.

12. "Redd building?" Hmmm? Is that a brick building? Are there any hints that might help us understand the term? No? Read the first sentence in the next paragraph of the article and define the term "redd building."

The redd or nest is usually constructed at the tail end of pools, where there is an insured supply of oxygenated water. The female turns on her side and violently thrashes her tail against the stream bottom, lifting rocks and silt which are carried downstream. She repeats this procedure many times, occasionally testing the depth with her anal fins. The male hovering nearby continues his courtship. Defense of territory is important and he lunges out aggressively with dorsal fin erect at any intruders. The female at times will also assist in defense. When completed, the redd is a hollow depression several inches deep and approximately twice the length of the fish.

13. Large numbers of salmon usually dig the redds in the same area. As salmon upstream lift rocks and silt, what happens to the recently excavated redds downstream?

The female drops into the redd and the male moves in beside her. Arching her back, thus positioning her vent well down in the redd, with a series of muscle spasms she begins to deposit eggs. Simultaneously, the male with a violent quiver releases the cloudy white milt. The pink eggs are sticky and lodge into the crevices of the rocky nest. Sperm must penetrate the micropyle, a minute opening in the egg, in approximately one and a

half minutes as the egg surface rapidly begins to harden. Recent studies have shown that the spermatozoa become very active in water and survive for only one to two minutes. The fertilized eggs are covered by the female as she moves upstream and repeats the redd building behavior. Newly disturbed rocks and gravel wash down over the redd to cover the deposited eggs. Spawning activity is usually during the night, as at this time predation and disturbance are at a minimum.

14. The sperm cells are released into the swiftly moving water. How might it be advantageous to the spawning of the salmon to have the water trigger activity in the sperm cells?



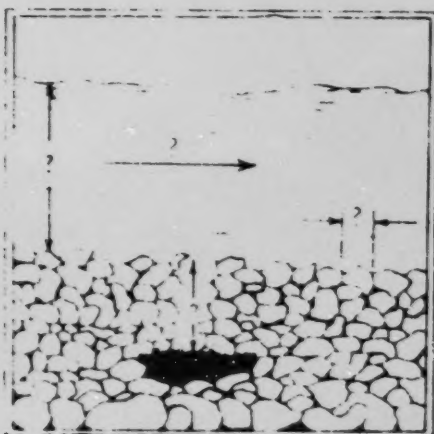
THE SPAWNING FEMALE TURNS ON HER SIDE, FANNING
VIOLENTLY WITH HER TAIL TO SCOOP OUT A NEST.

The spawning act is repeated many times until the eggs are deposited. The salmon, their bodies slowly wearing away, remain in the vicinity of their redds attempting to prevent new diggings, until too spent to swim, the current washes them downstream. By this time they are battered, bruised and a deteriorating fungus covers their bodies. Healthy fish have coatings of mucus to protect them from fungi and parasites. The spawning salmon lose this covering as their bodies break down to fuel the reproductive systems. None survive.

15. Rushing Creek has always had large numbers of salmon in its two breeding areas. Unfortunately, a tractor driver helping to log the area drove through both breeding areas. All of the eggs in the redds were destroyed. How will this action affect the future generations of salmon in this stream?

Rotting carcasses lie along the river banks, an important food source for all types of life. Birds such as gulls, eagles and ravens gorge themselves, releasing copious amounts of fertilizer in their droppings on the surrounding plant communities. Small organisms complete the recycling, releasing nutrients into the soil and water.

Development of Eggs



Not all of the eggs in the redd survive. Studies have shown that only a small percentage will hatch. Erratic water levels can leave them exposed or wash them downstream. Some are devoured by birds, migrating trout and resident fish while others are invaded by fungi.

In the developing eggs, rapid changes are taking place. Depending on water temperatures, but generally by mid-winter, eyes have formed in the embryo. A few weeks later tiny translucent alevins emerge from the egg sac. At this stage they will remain beneath the gravel until the yolk sac attached to their belly is absorbed.

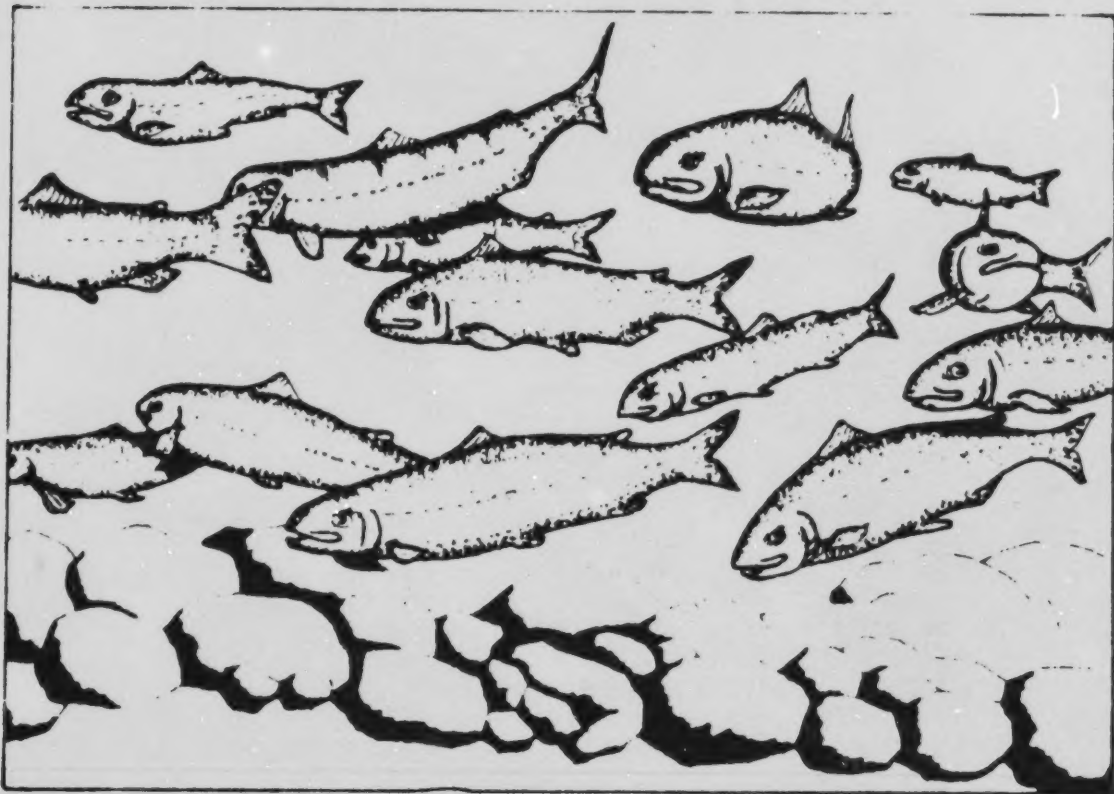
16. The alevins use the stored yolk material as food. After they absorb the yolk and leave the gravel, what are they called?

Young Salmonids

Some species remain in the stream as fry, while others migrate directly to a lake or to the sea. These movements are determined by water temperatures as well as by variety, and availability of food. As fry grow, vertical black bars, called parr marks, appear along their sides. These parr marks can be used as a means of identification between species.

While in nursery streams, the fry are receiving the necessary information which will enable them to return upon maturation. The nervous system of a fish is elaborate, yet the brain is small and not highly developed. There are practically no cerebral hemispheres, the part of the brain which stores impressions in higher animals, resulting in

memory ability. Experiments are being done to try to provide more information about homing. Some studies seem to indicate that there is also a genetic response as well as an imprinted response. In hatchery conditions, where the young are artificially reared, it is crucial that they be placed in the managed streams before this imprinting takes place. Experimental fish have been known to swim up sewer pipes trying to get back to the labs.



The migration from the nursery stream to sea is gradual. Rate of movement is determined by food, water temperatures, light conditions, hormone changes and the species of fish. As the fish enter the estuary they become smolts and spend

this stage of their lives physiologically adjusting to the saline environment. Scales develop, the silvery guanine coating appears and osmological (water balance) adjustments take place in the kidneys and gills. In this location they are vulnerable to heavy predation from a wide variety of birds and larger fish such as the cut-throat trout.

The juveniles then migrate in large schools following the coastal shoreline, feeding voraciously and growing rapidly. By late summer the salmonids have reached the oceanic currents, where they will continue to grow until it is their turn to spawn and die.

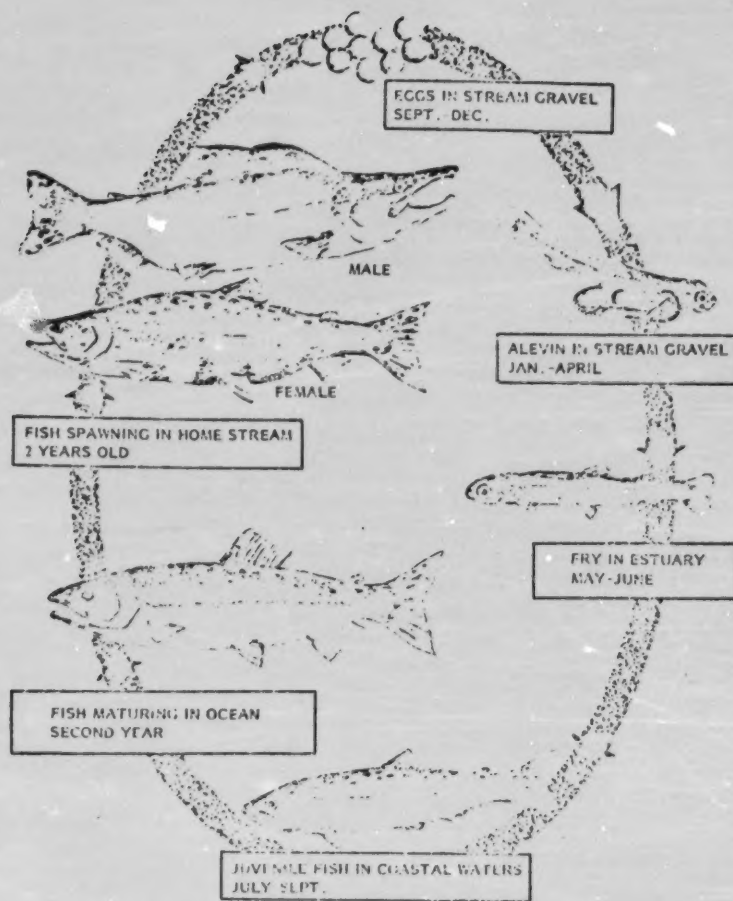
17. In the space below, beginning with a fertilized egg in a stream bed redd, trace the movements of a salmon until it dies after breeding.

Individual Species of Salmonids

There is no such thing as a typical salmonid. The different physiological characteristics and varying life styles make each species unique. Throughout the year, a river system may contain many species depending upon stream conditions, food availability and stream history. You can learn more about the specific life histories of each species of salmon by consulting available reference books.

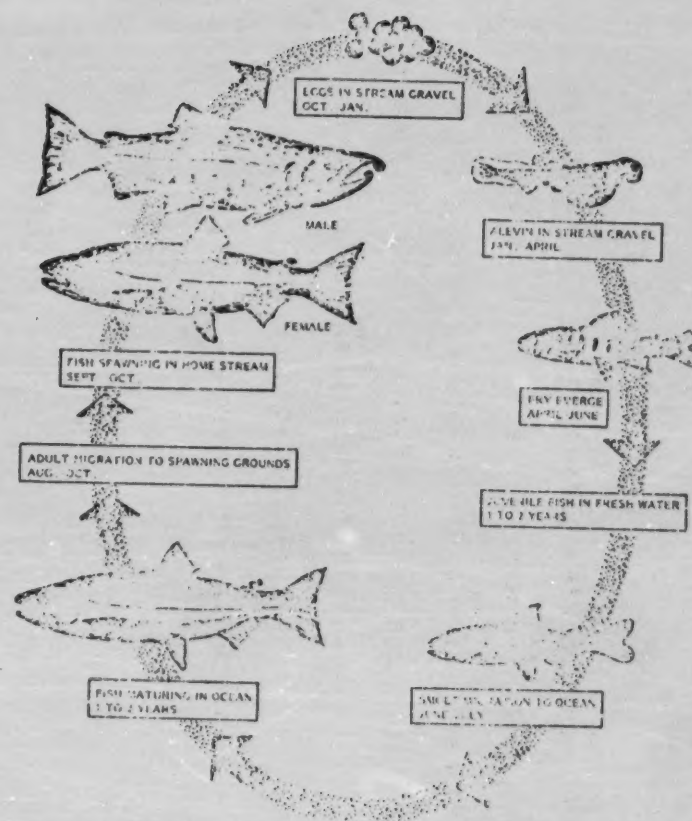
CYCLES

The different species of salmon have life cycles which are similar in many respects. The salmon are "born" in fresh water and eventually migrate to salt water where they spend part of their lives. The specific timing of these events differ between the different kinds of salmon. The life cycles of two of the common pacific salmon are shown on the next page.



Life Cycle of Pink Salmon

613



Life Cycle of Coho Salmon

610

745

Cycles

1. The _____ salmon is first to deposit eggs at the spawning grounds in the fall of the year.
2. As they dig their redds ("nests"), female _____ salmon are more likely to disturb the eggs of _____ salmon which were laid earlier in the season.
3. Alevin of both species obtain energy from the material stored in the yolk sack as they live in the stream gravels from _____ to _____.
4. _____ salmon move downstream as soon as they emerge as fry. _____ salmon, on the otherhand, remain in fresh water for from one to two years.
5. Both _____ salmon and _____ salmon mature while they are in the ocean.
6. _____ salmon have a highly regular two year cycle while the _____ salmon have a life cycle that can be from two to four years in length.
7. Salmon gain most of their body weight during the period they spend feeding in the oceans. Since they spend more time in the oceans we might expect that _____ salmon would be larger than _____ salmon.
8. Logging and road building operations can cause fine silt to be deposited in salmon streams. The silt fills the small spaces between the gravels in the stream bed. Poor logging and/or road building techniques would have the most effect on salmon in the _____ and _____ stages.

Silting is critical at these two stages because

_____.

9. Knowledge of the life cycle of a fish is important to people who make decisions regarding the number of fish available for catching (harvest). What are two other kinds of information these resource managers would find useful in making wise decisions?
- a. _____
- b. _____
10. Arrange the following stages in the life history of the salmon in their proper sequence by placing numbers in the blanks to the left of the stage. The first stage should be labeled number one and so on. The first stage is done for you.

_____ egg develop in the stream gravel

_____ fry emerge

_____ alevin in stream gravel

_____ fish mature in oceans

_____ fry or young fish swim downstream

_____ eggs are laid

_____ adult fish begin upstream migration to spawning grounds

1 _____ redds are dug

TEACHER BACKGROUND - The Homing Salmon - Three Level Guide

For centuries man has been fascinated by the migration of the salmon. The question of how salmon remember their birthplace and swim unerringly to it from a thousand miles away has been the subject of much scientific investigation. The following article from the "Scientific American" presents some of the pioneering work by investigators studying the homing of salmon. More recent research has expanded our knowledge of the process and you may wish to have your students locate and read current articles. The "Homing Salmon" article was chosen for the way in which it reveals the scientific process as well as for its content.

This article is difficult reading for many students. This article seems to typify a problem seen in teaching today: we can have articles that cover the material but are too difficult to read or we have articles that can be read but do not cover the material. The three level guide presented here is one way to solve this seeming dilemma. Three level guides are based on what seems to be the general agreement that comprehension can take place at different levels of cognition. Harold L. Herber has called these levels 1) literal, 2) interpretive, and 3) applied. With the exception of the literal level, each level requires the product of the previous level or levels in order to function. The literal level of comprehension produces knowledge of what the author said. We all recognize that it is quite possible to identify and even repeat what an author has said without understanding what the author meant by his statements. The interpretive level of comprehension depends upon the reading performed at the literal level but carries the process a step further. At this level the reader derives meaning from what the author has said. The meaning is determined by the way the reader perceives the intratext relationships. The applied level of comprehension takes the product of the literal, (what the author has said) and the interpretive (what the author meant by what he said) and applies it in some practical or theoretical exercise. At this level the reader is using his past experiences

and knowledge to produce new ideas which extend beyond those immediately identifiable in the reading selection. It must be borne in mind that the level at which a person reads does not reflect upon her intelligence and that the level can change as the material changes. The most advanced engineers and scientists often read at the literal level if they cross into other disciplines. When we read materials from an area with which we have little familiarity, our level of comprehension goes down. Your students are no exception to this observation. The three level guide is a device used to improve a person's comprehension by focusing on important concepts at each of the three levels. The three level guide can be used with any material and is readily constructed. For aid in this regard please see:

Teaching Reading in the Content Areas. 1970. Harold L. Herber. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 296 pages.

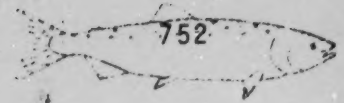
Duplicate the pages of the three level guide; one set per student. Spend a few minutes describing what is expected of the student. Suggest that the students read the statements in the three level guide before they read the article. In this way, the statements serve as a preview and your students will be looking for and expecting to see certain concepts. You may elect to have your students compare their answers by meeting in small groups. The process of resolving differences in opinion can be very instructive. Upon completion of the reading of the three level guide, discuss the guide by reference to the article. It is sometimes helpful to have your students note the page number and paragraph number where they found evidence supporting or refuting the statements in the guide. You can require your students to provide this information or you can offer extra credit for those that include it. Choose the technique that most appeals to you and best fits the needs and skills of your class.

KEY WORDS

decoy
ecological
function
fundamental
generalization
interpretation
migration
odor
paraphrase
salmon
spawning
structure

KEY

The Homing Salmon - Three Level Guide



Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those that you believe say what the author actually said or paraphrased in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference. Also, be ready to explain what is inaccurate about the statements that you do not check.

- ☒ Experiments designed to determine how salmon return to their birthplace could reduce fish losses at dams.
- ☐ Of the six common species of salmon, the Atlantic homes only once; after spawning they die.
- ☒ Research indicates that the salmon uses its sense of smell to identify the stream of its birth.
- ☐ Using a specially designed aquarium that injected odors into the water, biologists proved that salmon were unable to distinguish the odors of different plants.
- ☒ Young salmon become conditioned to the smell of their birth stream and are able to remember the smell as adults enabling them to find and follow the waters of their birth stream.
- ☐ Old fish remember odors better than young fish.
- ☒ Using odors to decoy homing salmon can help determine whether salmon migration is guided only by the sense of smell.
- ☒ Failure to decoy the salmon to a new stream, may mean that they will react only to a combination of odors in their parent stream.

Directions: Now compare your answers with those of others in your group. If there are many differences, find the page and paragraph that support your answer and write them next to the statement in question. When you finish your discussion, go on to the next level.

Level II. Directions: The statements below may or may not be true. Check each statement you believe is a generalization the author himself draws based on the information he gives in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference.

☒ _____

An understanding of salmon homing will help insure the survival of the Pacific salmon.

☒ _____

Each salmon stream is unique.

Little useful information can be obtained by marking young salmon and later recovering them as adults.

☒ _____

The structures the fish uses for smelling can give us information about how the sense of smell functions in the life of the salmon.

☒ _____

The salmon's sense of smell is highly developed and located primarily in the nose.

☒ _____

In the case of salmon homing, laboratory tests need to be coupled with field tests.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to next level.

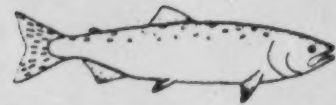
Level III. Directions: Read each statement below, relating the details and author's interpretations drawn from the selection to ideas and experiences you've had in reference to this topic. In column A, check the statements which Hasler and Larsen would have agreed with. In column B, check the statements you agree with.

A	B	
☒	☐	Directing the migration of salmon may lead to serious ecological problems.
☒	☐	Hydroelectric and irrigation dams pose a serious threat to the survival of salmon.
☒	☐	A combination of careful observation of nature and simple experimentation can provide a great deal of information about fundamental biological questions.
☒	☐	If man is to survive in ever increasing numbers, we will have to learn to respect, understand, and preserve all other living things.

Directions: Again, compare your answers with your group. Where there are differences, try to resolve them.

THE HOMING SALMON

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The Homing Salmon - Three Level Guide

Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and check those that you believe say what the author actually said or paraphrased in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference. Also, be ready to explain what is inaccurate about the statements that you do not check.

- _____ Experiments designed to determine how salmon return to their birthplace could reduce fish losses at dams.
- _____ Of the six common species of salmon, the Atlantic homes only once; after spawning they die.
- _____ Research indicates that the salmon uses its sense of smell to identify the stream of its birth.
- _____ Using a specially designed aquarium that injected odors into the water, biologists proved that salmon were unable to distinguish the odors of different plants.
- _____ Young salmon become conditioned to the smell of their birth stream and are able to remember the smell as adults enabling them to find and follow the waters of their birth stream.
- _____ Old fish remember odors better than young fish.
- _____ Using odors to decoy homing salmon can help determine whether salmon migration is guided only by the sense of smell.
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- _____ An understanding of salmon homing will help insure the survival of the Pacific salmon.
- _____ Each salmon stream is unique.
- _____ Little useful information can be obtained by marking young salmon and later recovering them as adults.
- _____ The structures the fish uses for smelling can give us information about how the sense of smell functions in the life of the salmon.
- _____ The salmon's sense of smell is highly developed and located primarily in the nose.
- _____ In the case of salmon homing, laboratory tests need to be coupled with field tests.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to next level.

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A	B	
_____	_____	Directing the migration of salmon may lead to serious ecological problems.
_____	_____	Hydroelectric and irrigation dams pose a serious threat to the survival of salmon.
_____	_____	A combination of careful observation of nature and simple experimentation can provide a great deal of information about fundamental biological questions.
_____	_____	If man is to survive in ever increasing numbers, we will have to learn to respect, understand, and preserve all other living things.

Directions: Again, compare your answers with your group. Where there are differences, try to resolve them.

TEACHER BACKGROUND - One Step Further

Authors, editors and publishers spend a great deal of time, effort, and money to produce the graphics which accompany printed works. The purpose of these graphics is, of course, to clarify and elaborate on the materials of the text. Unfortunately, many students do not use these aids to understanding. This exercise is designed to introduce the student to the utility of the figures included in "The Homing Salmon".

Plan to allow time for a discussion of the graphics and to provide the correct answers upon completion of this exercise.

KEY

Experimental Tank

1. The arrows in the drawing show the direction of waterflow.
2. Odorized water enters the tank through the deaeration funnel. (odor releaser should be crossed out).
3. Fish were conditioned to move toward one of the odors using food reward.
4. Fish were conditioned to move away from one of the odors by administering an electric shock.
5. The fish were blinded to make sure that they would not associate reward and punishment with the movements of the experimenters.
6. The experimenters should randomly alternate the sides from which the odors are released to make sure the fish would not associate a particular part of the tank with the reward or punishment. The answer to this question is not found directly in the drawing, but is a logical extension of the material included.

Four Runways

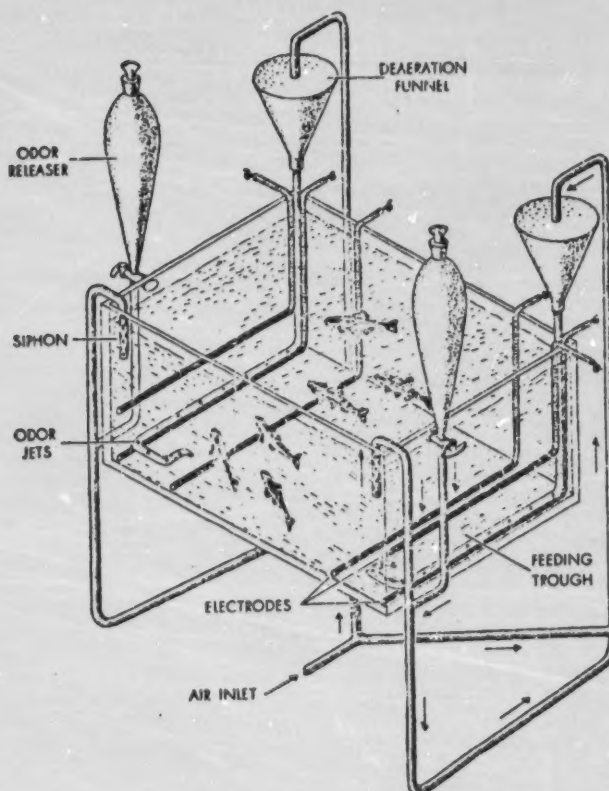
1. The effect upon the salmon fingerlings of an odor is judged by the observed distribution of the fish in the runways.
2.
 - a. Odor II and IV attracts salmon fingerlings.
 - b. Odor III repels salmon fingerlings
 - c. Odor number I has no effect upon salmon fingerlings.
 - d. The authors needed a substance which initially would not be either attractive or repellent to salmon but to which they could be conditioned so that it would attract them.
 - e. Odor I fulfills the authors' requirements for the substance needed for decoy conditioning.

KEY WORDS

association
attract
conditioning
deaeration
decoy
distribution
illustration
odor
punishment
repel
reward
salmon fingerlings

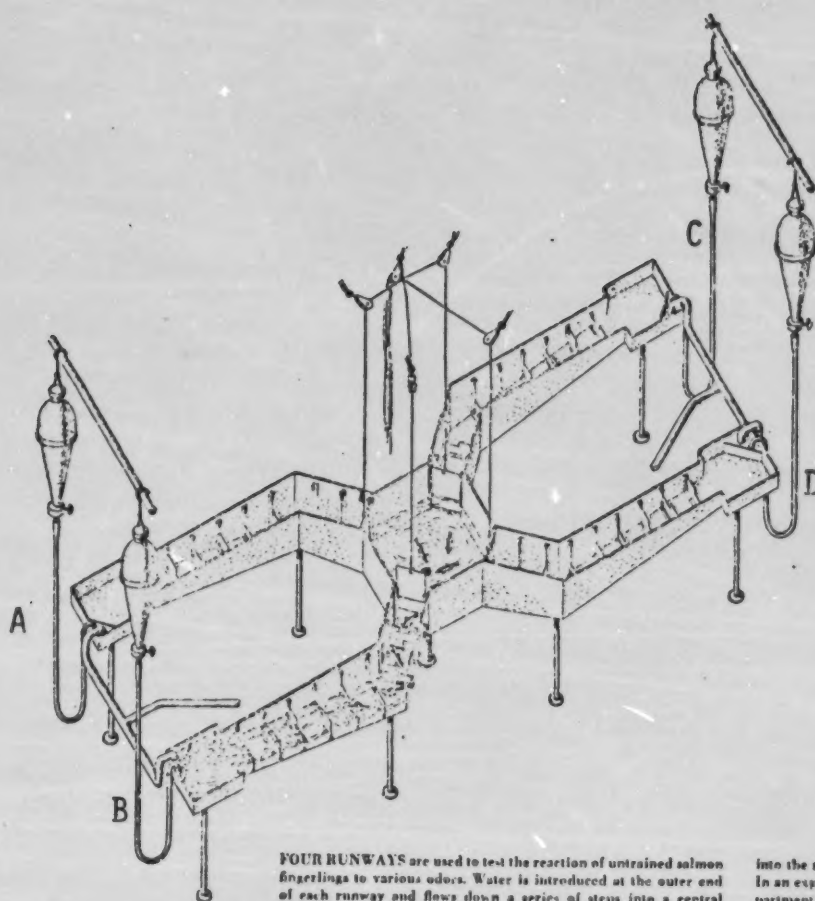
ONE STEP FURTHER

Arthur D. Hasler and James A. Larsen have provided us with several illustrations to help explain and expand upon the material in the text. Two of these illustrations are reproduced below. Use these copies to answer the questions which follow.



EXPERIMENTAL TANK was built in the Wisconsin Lake Laboratory to train fish to discriminate between two odors. In this isometric drawing the vessel at the left above the tank contains water of one odor. The vessel at the right contains water of another odor. When the valve below one of the vessels was opened, the water in it was mixed with water siphoned out of the tank. The mixed water was then pumped into the tank by air. When the fish (minnows or salmon) moved toward one of the odors, they were rewarded with food. When they moved toward the other odor, they were punished with a mild electric shock from the electrodes mounted inside the tank. Each of the fish was blinded to make sure that it would not associate reward and punishment with the movements of the experimenters.

1. What do the arrows in the drawing show the reader?
2. Odorized water enters the tank through the odor releaser/deaeration funnel (cross out the incorrect answer).
3. How were the fish conditioned to move toward one of the odors?
4. How were the fish conditioned to move away from one of the odors?
5. Why were the fish blinded?
6. Why should the experimenters randomly alternate the sides from which the odors are released?



FOUR RUNWAYS are used to test the reaction of untrained salmon fingerlings to various odors. Water is introduced at the outer end of each runway and flows down a series of steps into a central compartment, where it drains. In the runway at the lower left the water cascades down to the central compartment in a series of miniature waterfalls; in the other runways the water is omitted to show the construction of the apparatus. Odors may be introduced

into the apparatus from the vessels suspended above the runways. In an experiment salmon fingerlings are placed in the central compartment and an odor is introduced into one of the runways. When the four doors to the central compartment are opened, the fingerlings tend to enter the arms, proceeding upstream by jumping the waterfalls. Whether an odor attracts them, repels or has no effect is judged by the observed distribution of the fish in the runways.

1. How does the experimenter determine if an odor attracts, repels or has no effect upon the salmon fingerlings?
2. Over a period of time a number of different odors were introduced into Runway A. Each odor was allowed to flow until no further movement of the salmon was observed. The final distribution of the salmon after the various flows is shown below:

Odor Number	Number of Salmon in End of Runway			
	A	B	C	D
I	10	8	11	11
II	31	3	4	2
III	3	14	11	12
IV	22	6	5	7

- a. Which odor(s) attract salmon fingerlings? _____
- b. Which odor(s) repel salmon fingerlings? _____
- c. Which odor(s) has (have) no effect upon salmon fingerlings? _____.
- d. From the text, what were the characteristics required by the authors for a substance to be used in conditioning the fish in order to decoy them to a stream other than that of their birth?
- e. Which odor number fulfills the authors' requirements for the decoy conditioning mentioned in d. above? _____.

TEACHER BACKGROUND - The Fishing Rights Controversy - Salmon

"The Fishing Rights Controversy - Salmon" should be used in conjunction with "FISH GAME: A Puget Sound Fishing Game". The issues presented in this activity will be long with us. The economics of common goods such as salmon and clean water are complex. Management of the salmon resource is difficult because of the common goods nature of salmon. They only have value to the fisher and only when they are caught by that particular person. There is a built-in incentive to overfish and to keep undersized fish. The nature of the life cycle of the salmon permits a possible solution. The salmon return to particular streams to spawn. Russel L. Barsh from the University of Washington notes that this habit of returning to freshwater streams at regular intervals makes it possible to identify private ownership in the salmon during one phase of their life cycle. A self-regulating private property system in which individuals owned the salmon spawning in particular stretches of streams would replace all of the current methods of fishing. This proposal is not without its problems. The fish resource might well benefit from such a system since maximizing return to streams would become a prime consideration of the fish owners. For an interesting and detailed analysis of the economics of salmon fishing and the controversy surrounding U.S. v. Washington, please see:

Barsh, Russel L. 1977. The Washington Fishing Rights Controversy: An Economic Critique. University of Washington/Graduate School of Business Administration. Monograph Series. 61 pages.

Duplicate the text pages. One set is recommended per student. A discussion of property and property rights may be helpful background information for your students. Consider the differences between private and public property. You can illustrate the concept of common goods by placing a pile of raisins on a table or desk in front of the room. The raisins represent common goods. The rules of the game are as follows:

1. Each student is free to eat as many raisins as they want but they cannot hoard.
2. The raisins must be eaten immediately.
3. When the raisins are gone, they are gone.

The purpose of the exercise is to determine how long the resource will last recognizing that there is no incentive to conserve. The private property situation would occur if the M & M's were divided equally among students and the students were free to save, to trade or eat them at their discretion. Discuss the problems involved in conserving a common good. Ask your students to speculate on who would end up with all things of value in the world if there were no property laws.

As you discuss the material, explore the types of fishing gear mentioned and have your class hypothesize about the types of fishing gear that would be most common if no regulation existed and the possible effects on the salmon resource in the absence of regulation. With no regulation, the most efficient and economical gear would obtain, ie. purse seines. With no regulation, the tendency for each person to take as much as possible would be realized.

Your treatment of the issues involved in the interpretation of the phrase "in common with all citizens of the United States" must be sensitive to the feelings of your students. Avoid passing judgement on the decision - the decision was made and upheld. Focus on the results of the decision and the effect of the decision on the fishery, the salmon resource, and the people. Suggest that your students explore the issues more fully by consulting other sources including trial records.

"The Fishing Rights Controversy - Salmon" is best accomplished by individual students and may be assigned as homework or as an in-class assignment. Plan to devote time to a discussion of the issues mentioned above and to provide answers for the text questions.

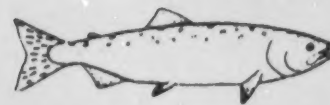
KEY

1. The two characteristics of a common good are:
 - a. the good has value
 - b. the good cannot be reduced to private ownership (owned by a private individual).
2. Overfishing is more likely to occur in situations where there is common ownership of the fish. Since there is no way to identify ownership, fishers will keep underweight fish. They will also keep all of the fish they catch because to let the fish go does not guarantee that the fish will live to breed. It will probably be caught by some other fisher. The mental attitude is "If someone is going to catch it, it may as well be me!"
3. Limiting the number of fishers allowed to fish is the regulation that differs from the rest. From an economic standpoint the other regulations are called "Regulation by Inefficiency", efficient and economical fishers are penalized.
4. Salt water fishing using nets and lines put the trap fishers out of business because the fish were intercepted before they reached the traps.
5. Since this is a "do you think" question, there are no right or wrong answers. It is probably easier for the Department to regulate commercial fishers if only from the standpoint of numbers; there are fewer commercial fishers. It is also easier to examine the catches of commercial fishers.
6. Answers will vary. This question is a good starting point for a treatment of the issues involved in U.S. v. Washington. Again, be sensitive to the feelings of your students. Avoid passing judgement on the decision while focusing on the results of the decision.
7. Since all of the treaty participants are dead, we no longer have the luxury of asking them what they meant by "in common with all citizens of the United States". The next best source of information is the treaties themselves, then the supportive documents made at the time of the treaties. If none of these are available, comparison with other treaties may be helpful. In the absence of any documentation, the meaning is entirely open to speculation.

8. In 1970, about 15 of the 100 salmon fishers would have been Indian. This question was included to help you ensure that your students understand the statement "proportional to the ratio of Indian to non-Indian fishers".
9. The federal court interpreted the treaties to assure tribes an opportunity to harvest up to 50% of the harvestable salmon returning to their "usual and accustomed" fishing places.
10. The court concluded that since tribal members owned relatively little modern gear, the goal could only be reached by requiring the state to give tribal fishers a longer season than other fishers.
11. The decision increased the amount of poaching and also created a situation in which the Department was forced to regulate the two groups of fishers differently. They now had to police all fishers fishing on Indian fishing days to determine who was legitimately entitled to fish. The complexity of the enforcement job increased significantly.
12. The immediate effect of the plan would increase the number of salmon in the rivers and sea by removing a chief predator. The long term effect on the salmon is difficult to assess since the carrying capacity of the habitat is dependent upon the quality of the surroundings, not only on the number of predators (fishers) present. The immediate effect on the fishers would be an increase in income. The long term effects on self-esteem, social relationships etc. are impossible to assess and your students' guesses are about as good as those of the experts.

KEY WORDS

anadromous
bag limit
common goods
compensation
extinction
Fifth Amendment
gear
gill net
Initiative 77
litigation
minimum escapement
perpetuate
probability
prohibited
proportional
purse seine
ratio
salmon
treaties
trolling
U.S. v. Washington



THE FISHING RIGHTS CONTROVERSY - Salmon

Who owns the salmon? No one or everyone? In the water, salmon have no identifiable owners. They do, however, have a monetary value - they're worth something. The case of salmon, a valuable fish with no owner, is called a common goods problem. A common good is something of value that cannot be reduced to private ownership (owned by a private individual), either because individual control is prohibited or because control is prohibitively costly. The air we breathe is an example of a common good. We all agree air is valuable (try holding your breath for five minutes!). Fortunately no one person has individual control over it. Everyone can take as much as they want. Salmon are also an example of a common good.

1. What are two characteristics of a common good?

Let's look at a stock of salmon that spend most of their lifetimes in the open ocean. The cost of tagging or "branding" each fish to identify their owners while the salmon feed and grow would be astronomical. Even if the salmon could be tagged like cattle, the tags could only be read by removing the fish from the water, a process that would injure or destroy many of them.

The problem with common goods is that no one has any incentive to conserve or improve them. Anything not consumed by one person will simply be taken and consumed by another.

For example, if a fisher has a choice of taking a three pound salmon or throwing it back, he will keep it. He will keep it even if the fish would quadruple in weight and value if allowed to mature. Unable to tag or otherwise identify the fish, the fisher has no assurance that she will recapture it. The probability is high someone else will catch it. The incentive is for the fisher to take every fish available.

2. Is overfishing more likely to occur in situations where there is private ownership of the fish or in cases where there is common ownership of the fish? Please explain your answer.

Because of the common goods problem, there is a tendency for fisheries to overharvest fish stocks into extinction. State and federal fisheries departments are charged with the responsibility of perpetuating the existing fish stocks. In other words, it is their job to keep the salmon from going extinct. Each race of salmon returns to the same location on the same stream at the same time each year. A minimum number of spawning fish or "minimum escapement" is necessary to perpetuate each run. To regulate the number of salmon taken, fisheries departments prohibit the use of certain kinds of gear (nets, hooks, etc.), they close certain areas to fishing, they allow fishing only on certain specified days, and they limit the number of fishers allowed to fish.

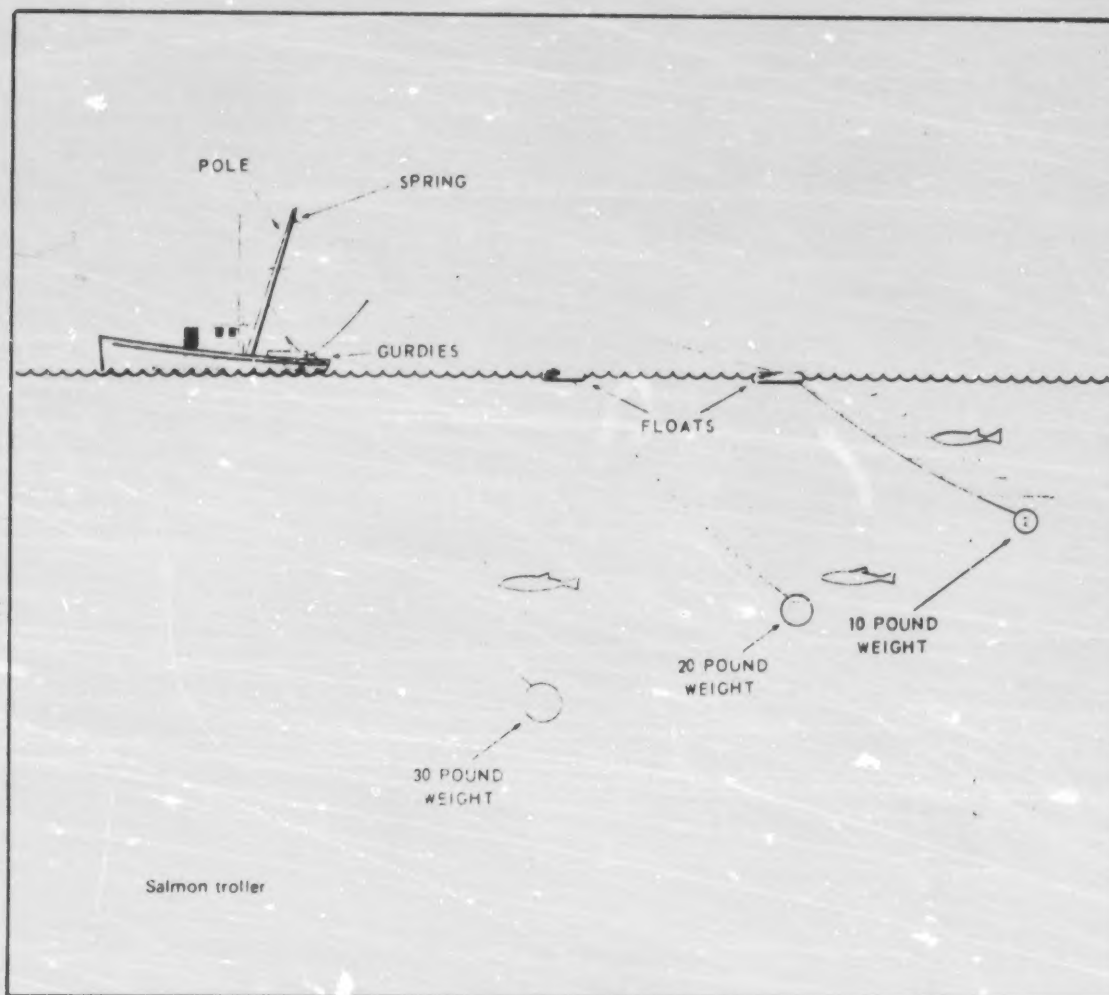
3. All of the above regulations except one are designed to limit the effectiveness of the individual fisher. Which regulation is the exception?

To understand the current problems, a little more background information might be helpful. Salmon fishing has changed a great deal in the last century. In the nineteenth century Indian tribes harvested most of the salmon in freshwater nets and traps. They waited for the fish to come to them and managed each stream independently. Non-Indian fishers originally imitated tribal traps, building larger and stronger ones. Trap fishers did well financially and were able to pay off the cost of their gear in two or three seasons.



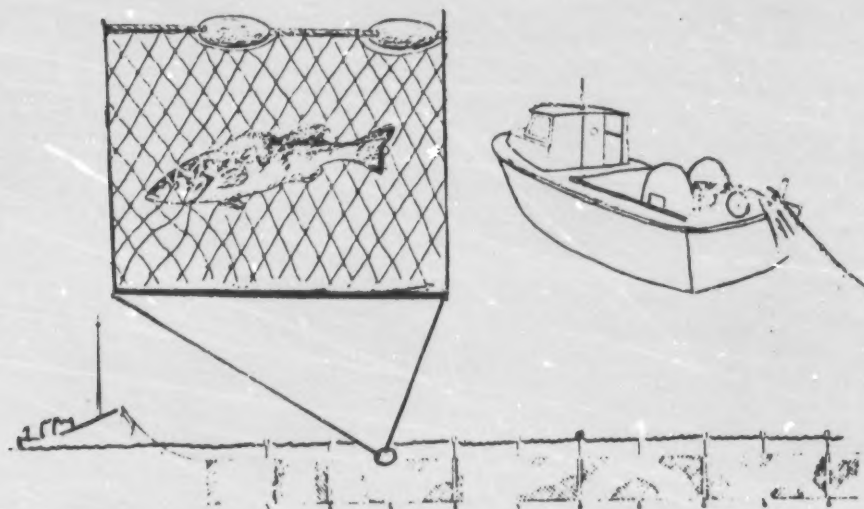
TRAP. This is a Puget-Sound-type "single heart" trap anchored by poles and designed to lead migrating salmon into its enclosure.

In deeper waters fishers began trolling--dragging hooked lines through the water.

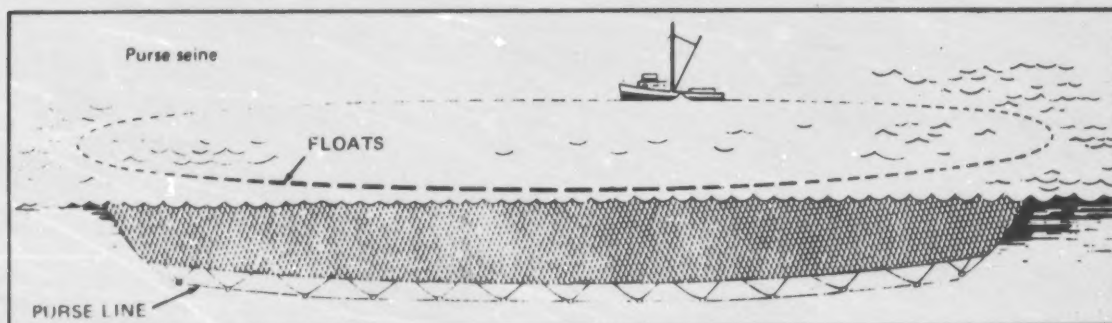


It cost more to catch salmon with gillnets, purse seines and trolled lines than with traps. However, once these new kinds of gear were put to use their ability to intercept salmon first out at sea put the trap fishers out of business.

After 1900, however, three new kinds of gear were developed which could intercept salmon before they reached the traps. Gill nets are drawn across the path of the fish. The salmon get caught, by their gills, in the mesh as they try to get through.



A purse seine is like a huge drawstring bag stretching around a school of fish and enclosing them.



Serious regulation of fishers began in the 1930's. In 1935 Initiative 77 banned all trapfishing and increased the powers and duties of the Department of Fisheries. Until 1974 no limit was placed on the number of people who could fish. To prevent overfishing salmon to extinction the Department in that year began the practice of limiting the times and places of fishing, and putting restrictions on the size and efficiency of each fishers' gear. The severest restrictions have always been on purse seines, the most efficient gear. This way, although the number of fishers more than tripled, the salmon have survived. Of course at the same time the number of salmon caught by each fisher has decreased.

Sport fishers have always felt the Department of Fisheries have been too generous with the commercial fishers. For forty years or more there have been more sport fishers than commercial fishers, and their number has been growing constantly. There are today nearly a hundred sports fishers for every commercial fisher, and as a group sportsfishers take about one out of every six salmon in the state waters. Like commercial fishers, sportsfishers must pay a fee to fish, but there is still no limitation on the number of licenses. To prevent overfishing, sportsfishers are subject to a limited fishing season, a "bag limit", and limits on the size of fish they may catch and keep.

5. Which group of fishers do you think it is easier for the Department of Fisheries to regulate: the commercial fishers or the sports fishers? Please explain your answer.

As if the controversy between commercial and sports fishers was not enough, there is now a serious controversy within the commercial fishers' ranks. The controversy centers on the decision handed down in the 1974 court case, U.S. v. Washington which dealt with the interpretation of Indian treaties. As can be seen in the following portion of the transcript, the courts recognized the historical importance of the salmon runs to the native Americans:

In pretreaty times Indian settlements were widely dispersed throughout Western Washington. There was considerable local diversity in the availability and importance of specific animal, plant and mineral resources used for food and artifacts. But one common cultural characteristic among all of these Indians was the almost universal and generally paramount dependence upon the products of an aquatic economy, especially anadromous fish, to maintain the Indian way of life.

U.S. v. Washington (1974)

Perhaps we can make some sense out of the issues if we look at their historical background. Indian treaties are the principal written documents that remain from all the original negotiations. The nine treaties signed in 1854-1855 with the Indian tribes of Washington and Oregon all promise to protect the tribes' "right of taking fish at all usual and accustomed grounds and stations...

in common with all citizens of the United States," or similar words to that effect. Exactly what was intended is unclear. Transcripts of the treaty negotiations shed no light on this question. Tribes must have thought this was a valuable right, since it was almost all they received in return for millions of acres of land. When they signed these treaties, Washington tribes had no competitors for the salmon in these waters.

6. How would you interpret the treaty phrase..."in common with all citizens of the United States?"

7. How could you find out what the treaty participants intended the above phrase in number 6 to mean?

By the late 1800's the economic value of the salmon runs was recognized by non-Indians. Although Indians fished on the open seas with many kinds of nets, hooks and harpoons, most Indian salmon fishing was by traps, nets and weirs anchored in the rivers. By 1900 non-Indians were building larger traps in deeper water and in addition, were intercepting salmon from boats, before the salmon reached Indian traps. To make matters worse, Indians were unable to borrow money to buy the kinds of traps, boats and gear used by non-Indian fishers. Although Initiative 77 of 1935 did not apply to Indian fishers,

many Indian traps were demolished in the 1930's. By 1940, the Indian share of the statewide salmon harvest was only about 6%. Over the years federal and private credit gradually became available to Indian fishers. As they began to buy boats and compete with non-Indians using the same kinds of gear, their share of the statewide harvest rose (by 1970) to almost 15%--about proportional to the ratio of Indian to non-Indian fishers.

8. In 1970 out of a random sample of 100 salmon fishers, about how many would have been Indian?

In 1974, the situation was drastically changed. U. S. v. Washington began as a challenge by members of the Nisqually and Muckleshoot tribes to Washington state's general licensing, area and season regulations. In 1974 the federal court interpreted the treaties to assure tribes an opportunity to harvest up to 50% of the harvestable salmon returning to their "usual and accustomed" fishing places, as well as a reasonable number of salmon for subsistence. The court concluded that this could only be accomplished by requiring the state to give tribal fishers a longer season. The tribes are to be "self-regulating" on their own reservations and, in some cases, off-reservations as well. The federal district court continues to serve as the ultimate arbiter of disputes between tribal and state regulatory

agencies. As a result of the court's ruling some tribes now come close to enjoying 50% of the salmon in their waters, but statewide the Indian share is probably not more than 25%.

9. How did the courts elect to interpret the phrase "in common with all citizens of the United States?"

10. How did the court act to accomplish this goal?

As you might well imagine U.S. v. Washington created much bitterness among commercial fishers. The immediate effect of increasing the number of days of fishing for Indian fishers and reducing the number of days for non-Indian fishers was to reduce the income of the non-Indians. Needless to say, the non-Indians felt persecuted. Many felt justified in disobeying the law. As a result, poaching increased and the job of the enforcement arm of the Department of Fisheries became a nightmare. In the simulation game that follows you will have a chance to see what it's like to be a salmon fisher in Puget Sound and also to see what it's like to be a regulator for the Department of Fisheries.

11. What are two ways in which the decision is U.S. v. Washington increased the difficult job of enforcement held by the Department of Fisheries?

What does the future hold? Northwest Indian treaties cover all kinds of fishing, shellfishing, whaling and sealing. Will future court action expand U.S. v. Washington? Future litigation is inevitable, particularly over herring, smelts and clams. An even more significant issue that remains open is the state's and United States' liability to tribes for the widespread environmental damage that has reduced all stocks of shellfish and anadromous fish far below their pretreaty levels. If treaties gave tribes a property right in the fishery, these reductions in fish populations may have constituted a taking of property subject to the Fifth Amendment's requirement of compensation. In other words, if the treaties gave ownership to the tribes, the government may have to pay the tribes for the fish and shellfish damage.

With respect to the salmon fishery, fishers' incomes continue to fall. Environmental damage to spawning grounds and foreign fishing outside of our territorial waters continue to pose a much larger threat to the Northwest fish harvest each year than changes brought about by treaty rights litigation. In 1900 fishing was this state's third largest industry. Today it accounts for less than 1% of the state's economic output. The fishing industry's former economic significance might be regained through rebuilding and supplementing natural spawning grounds, more efficient fish harvesting technology,

and better and simpler overall management. If current trends continue, however, the fishery may soon cost more to manage than the value of the fish caught.

12. If the fishery does indeed come to cost more to manage than the value of the fish caught, it would make good economic sense to take the money spent on regulation and management and divide it among the fishers. How would this plan affect the salmon? How would it affect the fishers?

In the final analysis the future of the Northwest fishery lies in the hands of the state and the tribes. Everyone benefits from an improvement in the economic value of the fishery. The problem is to arrive at an agreement to manage the fishery in the best possible way. This may only happen if state and tribal citizens begin to see the real problem as one of increasing the total value of the fishery, rather than disputing the distribution of its current, reduced and still declining value.

TEACHER BACKGROUND - Fish Game: A Puget Sound Salmon Fishing Game

"FISH GAME: A Puget Sound Salmon Fishing Game" is a simulation game designed to expose your class to some of the concerns and frustrations of salmon fishers and fisheries regulators. Your class will get the most out of FISH GAME if they first understand the migratory life-cycle of salmon (see "The Salmon Story" and Cycles").

"FISHGAME: A Puget Sound Fishing Game" is adapted from:

Barsh, Russel L. 1978. Understanding Indian Treaties as Law. Prepared under the supervision of The State Superintendent of Public Instruction; Olympia, Washington. 74 pages.

Preparation

1. In some manner, assign students to be fishers and regulators and distribute instructions to the class the day before you play FISHGAME. There must be only twelve individuals or teams fishing.
2. Each student will need a copy of the general instructions and a copy of the student "scorecard" included in this packet. Explain the use of the scorecard when you distribute it. Number the fishers' scorecards from 1 to 12. These will be their identifying "boat numbers."
3. Before your class meets to play FISHGAME, paste or tape together the four sheets that make up the FISHGAME BOARD. Also make a transparency of the "fishcard" included in this packet and cut it out with a scissors. Finally, make ten copies of the "bad news cards," cut them apart, and shuffle them like a deck of playing cards.
4. Just before your class arrives, arrange all tables and chairs in a semicircle around your desk, leaving plenty of room in the middle. Lay the FISHGAME board on your desk facing the class or display it on the blackboard.

5. Trace the migratory path of the Dungeness salmon run used in FISHGAME on the FISHGAME board as you discuss these questions:

Where are the salmon closest together and easiest to catch? Farthest apart and hardest to catch?

Where are the salmon easiest to find? Easiest to tell apart from other runs of the salmon? Hardest to tell apart?

Where are the salmon largest and fattest?

What are some different ways people could fish for salmon? On the basis of what you know about the life-cycle of salmon, where and how would you prefer to fish to make the most money? To catch the largest numbers of fish?

How can anyone tell how many salmon have already been caught during a season? How many are still left in the water uncaught?

Beginning play

1. Have a student helper deal out the "bad news cards," one card to each student fisher. Students must follow the instructions on these cards.
2. As soon as all the fishers have been dealt cards, announce that fishing will begin. Each fisher indicates where he wants to fish by writing his boat number on that spot on the FISHGAME board. Give fishers no more than five minutes for this.
3. When everyone has returned to their seats, score the round using the transparent fishcard. Never let the class see the fishcards!
4. After scoring, ask the Department of Fisheries to announce any time or area closures they wish to make for the next fishing day. Then have the "bad news" cards dealt again and start over. FISHGAME is designed for six fishing days or rounds.

Scoring

1. The fishcard has printed on it 36 dots in 18 squares. Each dot represents 100 salmon.
2. To score each fishing day or round, place the fishcard on the board so that it corresponds with the marker (a triangle) for that day. There are six markers, numbered from 1 to 6.

3. If a boat number falls within a square containing any dots, cross off one dot in that square, calling off the boat number and its catch, that is, "boat number--, 100 fish!" If a boat falls between two squares it "catches fish" in only one of them. If all the dots in a square are crossed off, no more fish can be caught in that square. No fish can be caught on "land."
4. When the game is over, each fisher should have his own record of how many salmon he caught, and you should have a record, on your fishcard, of how many salmon survived to "spawn".

U. S. v. Washington version

1. As just described, FISHGAME simulates a salmon fishery before the Indian treaty fishing rights decision, U.S. v. Washington. It does not distinguish among different groups of fishers.
2. To play FISHGAME as a simulation of the treaty-fishing situation, identify, before game play, three fishers (or fishing teams) as tribal fishers. All rules of FISHGAME stay the same except that non-tribal fishers can only fish on even-numbered fishing days.
3. This version of FISHGAME is most instructive if played after the standard version.
4. After you play this version of FISHGAME, discuss with your class the following questions:

How much better off were the individual tribal fishermen as a result of the fishing-days rule? Will this advantage last long if other tribal members, attracted by the new law, start fishing, too?

Was it harder for the Department of Fisheries to do its job as a result of the fishing-days rule? Why?

How did the fishing-days rule affect the total salmon catch of both groups?

The issues presented in FISHGAME represent only a portion of the problem. Supplement this activity with articles from newspapers, magazines, etc. that treat recent developments. Encourage your student to find and share these pertinent articles. The conflicts are far from resolved and the effects of the solutions are likely to be widespread.

KEY

Answers to the "Debriefing Questions" depend upon individual experiences. Use these questions as a springboard for discussion of the issues involved in the fishing rights controversy.

KEY WORDS

controversy
debriefing
enforcement
escapement
extinction
fisher
fishery
fishing rights
gill nets
migration
minimum escapement number
model
predictions
regulator
salmon
U.S. v. Washington
violation

BAD NEWS

YOUR BOAT SPRINGS A
LEAK. GO BACK TO
THE DOCK; NO
FISHING FOR YOU
TODAY!

BAD NEWS

STORMY WEATHER
KEEPS YOU TIED UP
AT THE DOCK; NO
FISHING FOR YOU
TODAY!

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

BAD NEWS

approximate
path of salmon

cape
flattery

neah
bay

MAKAH
INDIAN
RESERVATION

OLYMPIC
PENINSULA

N
SCALE
1 inch = 2 miles

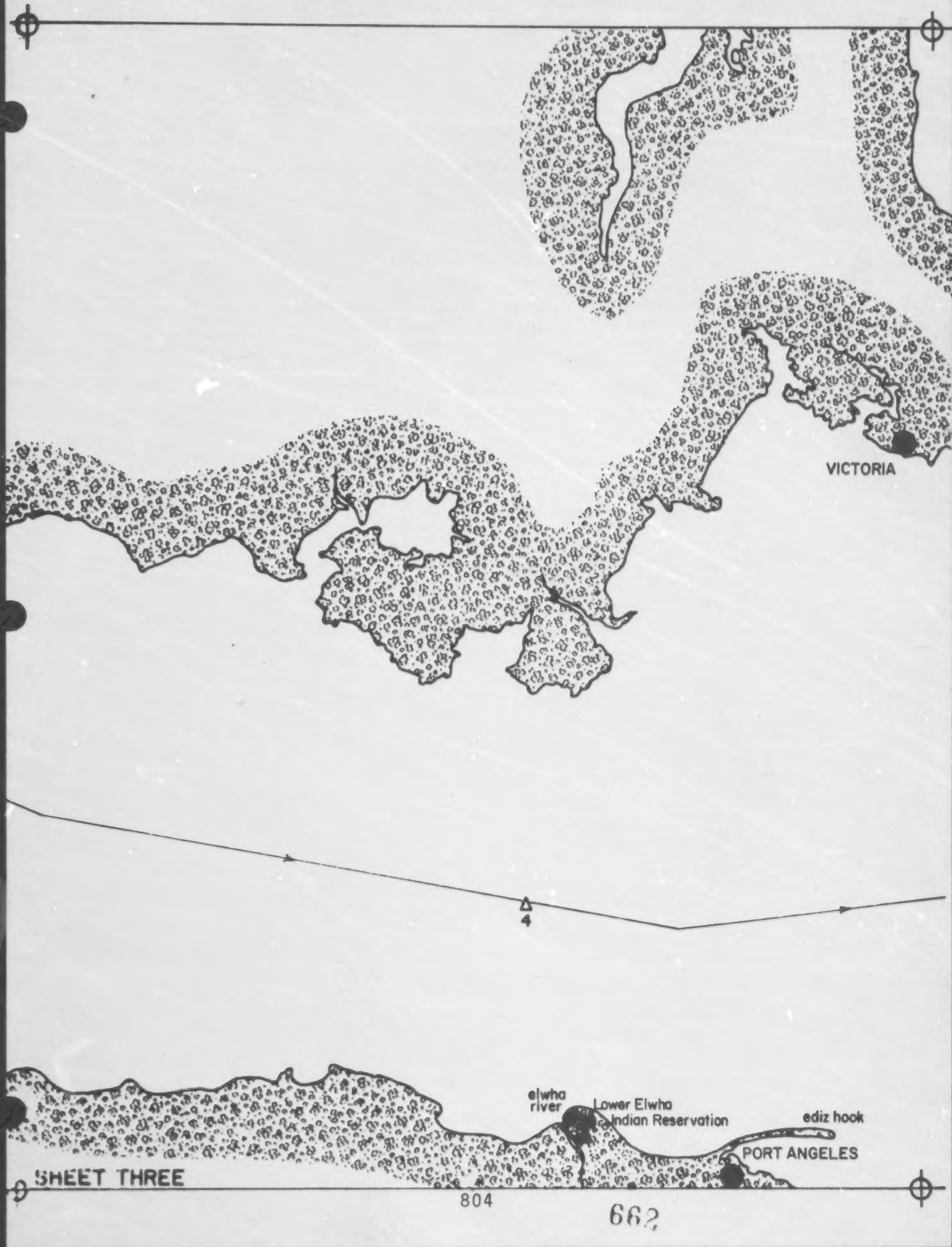
cape
alava

SHEET ONE

802

660





VICTORIA

elwha river

Lower Elwha Indian Reservation

ediz hook

PORT ANGELES

SHEET THREE

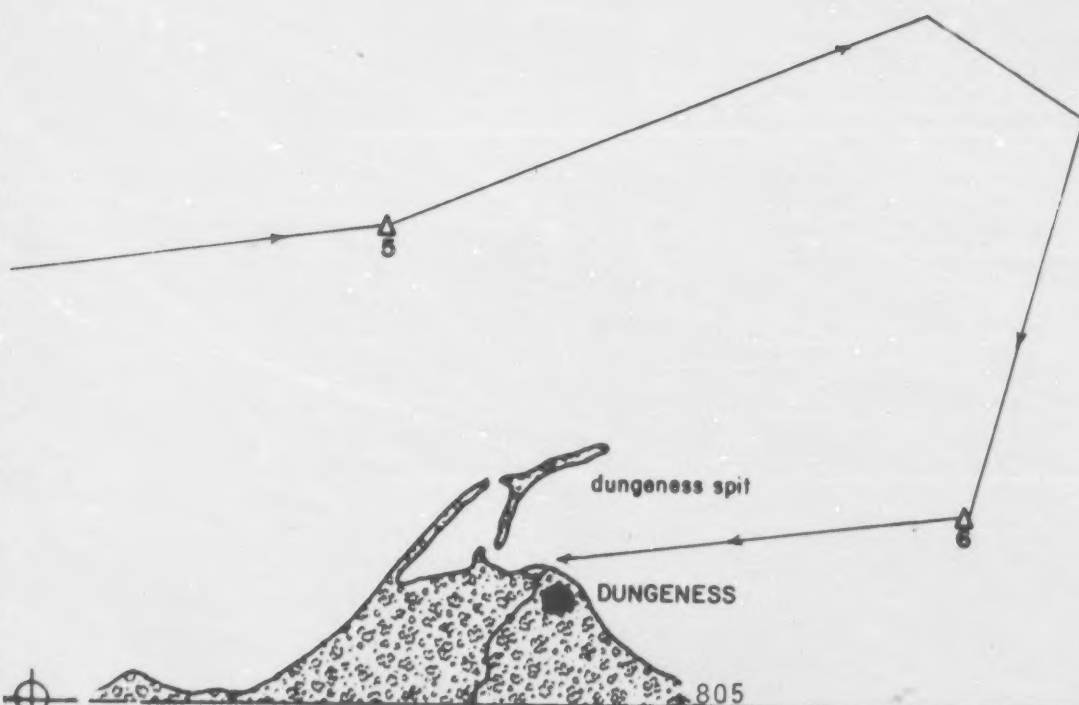
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the fishgame

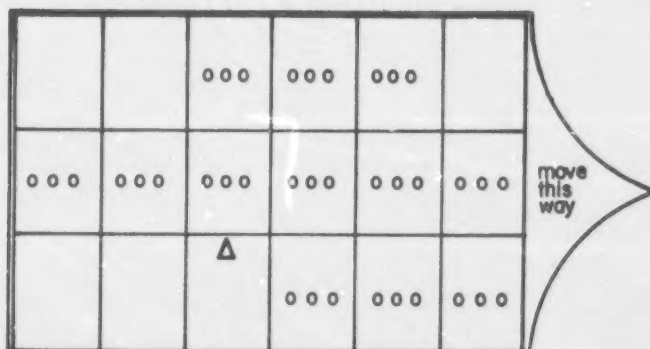
GAME BOARD

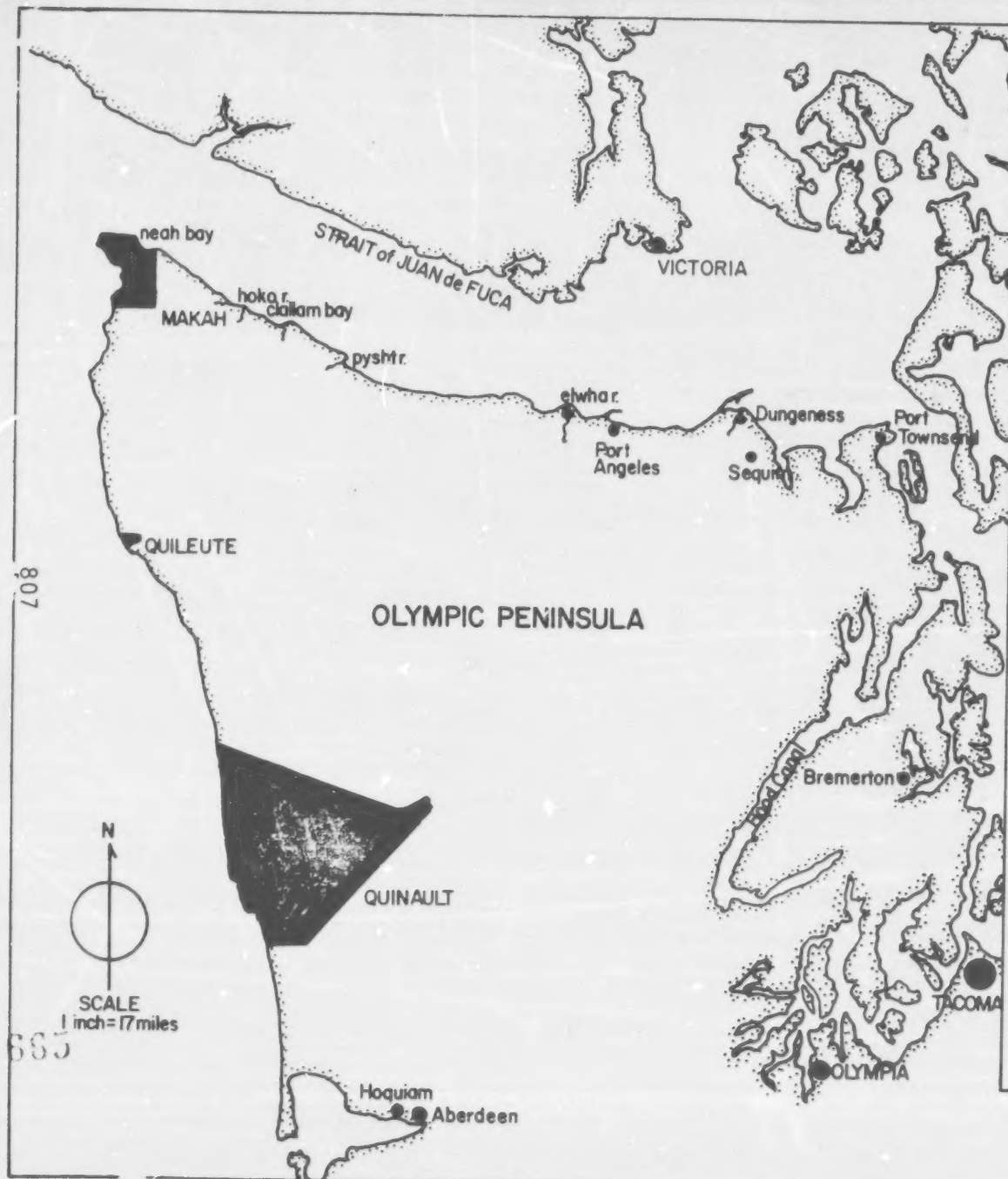


SHEET FOUR

this is your fishgame FISHCARD

Each o represents 100 SALMON
The Δ is the point of alignment





fishgame SCORECARD

BOAT NUMBER _____

NAME(S) _____

FISHING DAY _____

YOUR CATCH

1 _____

2 _____

3 _____

4 _____

5 _____

6 _____

SEASON _____

=====

660



FISHGAME: A Puget Sound Salmon Fishing Game

What's it like to be a salmon fisher in Puget Sound? What kinds of risks do fishers take? How easy is it for fishers to find fish, and how easy is it for fisheries regulators to tell when too many fish are being caught? How are all of these things affected when different groups of fishermen are required to fish at different times, as is the situation after U.S. v. Washington?

You will have a chance to explore some of these questions about the Washington fishing rights controversy with FISHGAME.

FISHGAME is a very simple model of Puget Sound salmon fishing. In FISHGAME, fishers compete for a single run of salmon migrating to the Dungeness River near Sequim, while enforcement agents, working together as the Department of Fisheries, try to prevent the run from being overfished to extinction. All of the fishers use the same kind of fishing gear (gill-nets). Random accidents (bad weather, boat trouble) cause some fishers to lose fishing days.

Of course, in real life there are hundreds of runs of salmon and fishermen use different kinds of gear.

GENERAL INSTRUCTIONS

The Game

1. There are two groups of players. Twelve students (or, if you wish, twelve teams of students) will be fishers. All of the rest will be the Department of Fisheries.
2. There will be one run of salmon, migrating to the Dungeness River to spawn. It will make the trip in six days, following roughly the path indicated on the FISHGAME board. The salmon will be spread out on both sides of the migration path for ten miles or more.

Object of Play

1. The job of the fishers is to catch as many fish as they can. Any fisher who catches no fish can't make the payments on his or her boat and loses it.
2. The job of the Department of Fisheries is to preserve the Dungeness salmon. This requires that at least 800 salmon reach the river to spawn; 800 is the "minimum escapement number."

Fishing

1. Each fisher will have a scorecard, consisting of a map of the Strait of Juan de Fuca and spaces to record his/her daily catch. Fishers can use their scorecards to plan where they will fish and to add up their scores.
2. Before each fishing day each fisher will be dealt a "bad news card." Most of these cards are blank, and can be ignored. A few, however, mean boat trouble, storms, or other problems that will keep fishers from fishing. Fishers must follow the instructions on the cards they draw.
3. When the teacher announces the beginning of a fishing day, each fisher indicates where he wants to fish by writing in her boat number (from her scorecard) on that spot on the large FISHGAME board.
4. After all boat locations have been written in for the day, the teacher will score that round. If a fisher has caught any fish, the teacher will announce it (for example, "boat number five, 100 fish!"). Fishers should not only keep careful count of their own catches, but find out how well other fishers are doing to get a better idea of where the fish are running most plentifully.

Regulations

1. Each member of the Department of Fisheries also has a scorecard. Members of the Department use the scorecard to try and keep track of the number and location of fish caught.
2. Members of the Department have a right to look at any fishers' scorecards at any time.
3. The Department can, at the beginning of any fishing day, close down all fishing that day, or close down all fishing in any part of the FISHGAME board that day. If any fisher is caught fishing in violation of one of these Department orders, the Department can, after checking with the teacher (who is final judge in these matters), take away his day's catch, his boat, or both.
4. To help the Department plan what action it will need to take to see that at least 800 salmon make it back to the Dungeness, these historical statistics are offered:

<i>Year</i>	<i>Salmon Caught</i>	<i>Escapement</i>	<i>Total</i>
1970	2700	1200	3900
1971	2400	1000	3400
1972	2300	1700	4000
1973	2800	800	3600
1974	2300	900	3200
1975	2400	1600	4000
1976	2500	1000	3500
1977	2700	1000	3700
1978	2000	1100	3100
average	2423	1144	3567

DEBRIEFING QUESTIONS

Debriefing questions for fishers:

1. How did you go about trying to predict where to find the salmon?
2. How successful were your predictions? Why?
3. How often were you unable to fish where and when you wished?
4. How well were your own efforts and skills rewarded? Did your catch reflect your effort and abilities?
5. How would you change the fishery to give yourself a better chance to make a good catch in the future?

Debriefing questions for regulators:

1. How did you go about trying to predict the numbers and movements of the salmon?
2. How successful were you? Why
3. What could you have done to do a better job of prediction?
4. How effective were your regulations in protecting the salmon runs? Were problems caused by
 - (a) poor information
 - (b) badly-designed regulations
 - (c) little compliance from fishers
 - (d) poor enforcement
 - (e) all of these? How?
5. How would you change the fishery to make your job easier the next time?

BIOLOGICAL FACTORS:

Marine Mammals

TEACHER BACKGROUND - Marine Mammals

Next to sharks, marine mammals hold the greatest fascination for students. The sheer magnitude of the great whales is overwhelming. The streamlining of the seals is impressive. Their big eyes are "sympathetic". All of these attributes and more tend to give marine mammals a special place with your students. Whether it be whaling issues or harp seal hunting, marine mammals are frequently in the news today. This section is designed to give a brief introduction to the more common marine mammals. Dugongs, manatees, and sirens have been omitted in favor of focusing on the more common marine mammals. If time permits, encourage your student to prepare reports on these and other lesser known marine mammals. The goal for this section and all of the sections on marine mammals is to give your students the factual information they will need to analyze and evaluate the many conflicting articles and opinions that they will see in print and on television. This is no easy task since most of your students will come to this section with a set of predetermined ideas and values. Strive to provide the factual basis for a review of these ideas and values. Be aware when you interject your opinions and values and be sure to make the distinction for your class between opinion and fact. This is an exciting topic. Enjoy.

Since most of your students will have had limited personal contact with marine mammals, supplement these materials with films, filmstrips, charts, posters, and other available teaching aids. A list of sources for additional information is found after the "Key Words" section following.

Duplicate the activity pages. One set is recommended per student. This activity lends itself to completion by individuals as homework or as an in-class assignment. Whichever approach you elect, plan to provide your students with the correct answers to the text questions during a discussion of the concepts and materials presented in the reading.

KEY

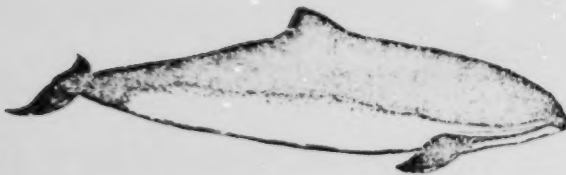
1. The two characteristics that all mammals share are:
 - a. hair; and,
 - b. feeding their young with milk from mammary glands.
2. Countless environmental factors impinge upon marine mammals. The most obvious for which we might expect to see special adaptations include: temperature, light, oxygen, food availability, salinity, dissolved materials, predators, etc. This question is designed to provide a springboard for a discussion of the difficulties a mammal faces in the marine environment.
3. The two primary ways in which marine mammals deal with cold water temperatures are: insulating hair and insulating fat layers. There are also a myriad of more subtle ways in which marine mammals cope with water temperature. For example, these include sophisticated circulatory patterns that allow reduced circulation to certain areas resulting in a reduction in heat loss.
4. The ability to dive deep and stay down a long time enables the whale to feed at many different levels. It also may help whales escape danger from storms, hunters, etc. Your students may have additional ideas.
5. This question is likely to be frustrating for your students. Part of the frustration will stem from the fact that the "hypothesis" as stated is nearly impossible to prove or disprove.

We might be able to determine whether the sea chirps are warnings by subjecting one group of marine mammals to some stress, such as a pollutant, while observing a similar group not under stress. Recorded differences in sea chirps might be attributed to the stress. Whether we could consider them as "warnings" is difficult to say. The problem lies in the fact that we have attributed human attributes (the ability to perceive and reason and warn) to marine mammals. While the marine mammals may indeed have these capabilities, our scientific methods are ill equipped to determine whether what we hear are warnings. They

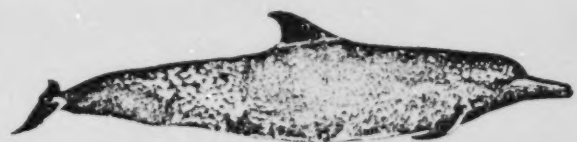
could well be just that. The question can provide an opportunity to discuss the article and the problems with newspaper abbreviated articles or to discuss the problems of experimental design in this type of situation or to discuss communication in marine mammals. The article could also be used as a springboard for a discussion on man's interaction with marine mammals. This latter discussion, however, might better occur later, after your students have gained a factual background about marine mammals.

6. As the whale swims into a mass of plankton, water containing plankton rushes into its mouth. The tongue is pressed toward the roof of the mouth forcing the water out through the baleen. The plankton is caught on the baleen "hairs" and the excess water squirts out the sides of the mouth. When a mouthful of food has built up on the baleen, the whale licks it off with its tongue. The text provides only limited help in answering this question. The answer comes from a careful look at the picture and the text statement that "Baleen whales feed on plankton, strained through the baleen..." This question is a test of logical thinking. Be on the lookout for logical, albeit incorrect, answers.

7.



Harbor porpoise



Eastern Pacific spotted
dolphin



Blue and white dolphin



Dall's porpoise

8. Since this is an opinion question, there are no right or wrong answers. A major reason for whaling continuing involves the common goods question discussed in previous activities dealing with salmon. Since no one owns the whale, there is no incentive to manage (or conserve) it. A second important reason stems from the fact that whaling nations and individual whalers have large capital investments in whaling equipment. While the economic return may not be enough to pay the total cost of the operations, the loss incurred by operation is less than the loss incurred by not operating. Economic incentives, then, are the major reason that whaling continues. The benefit is to the individual, the cost is to society as a whole.
9. This question treats a touchy subject. When a fisher witnesses a marine mammal eating one of the animals the fisher is pursuing, the fisher is inclined to blame the marine mammal for the poor fishing. This line of reasoning is not hard to understand, the fisher can see the action and knows that a salmon or abalone eaten by a marine mammal is one less for her to catch. The results of pollution, overfishing, or mismanagement of the fisheries resource are not as clearly defined. Nonetheless, overfishing, pollution, habitat alteration, and poor management are more likely causes of reduced fish catches.
10. Eared seals can turn their hind flippers forward, enabling them to move rapidly on land, hair seals are clumsy on land and less likely to be found ashore.
11. The current population size estimate for harp seals is only 13 per cent of the historic figure.
12. The answers depend upon experimental observations. This question is designed to further your students' appreciation for the diving abilities of marine mammals.
13. If the sea otter populations were reduced in number by hunting, the sea urchin populations would probably increase since the sea otter is a predator on sea urchins.

14. If the number of sea otters was reduced by hunting, the kelp beds would suffer increased grazing from the increased number of sea urchins.
15. Kelp harvesters would want to encourage sea otter population growth because sea otters are effective predators on sea urchins. Question 13 - 15 point out some of the complex interdependencies that exist in the marine environment.
16. Yes, the observed results would have been a predictable outcome of widespread sea otter hunting because reduced sea otter numbers tend to allow the sea urchin numbers to increase which tends to decrease the extent of the kelp beds.
17. This is an opinion question in which there are no right or wrong answers. The question should provide you with an opportunity to discuss the problem and for some discussion of the relative merits of each side of the argument.

KEY WORDS

abalone
adaptation
ambergris
baleen
bouyancy
Cetacea
chirp
Chordata
controversy
diversity
dolphins
extinct
flipper
furbearer
harems
insulation
kelp
mammal
Mammalia
mammary glands

niche
 pinnipeds
 plankton
 population
 porpoise
 proportionally
 rookeries
 sea lion
 sea otter
 sea urchin
 seal
 spermaceti
 structural adaptations
 taxonomists
 ventricles
 Vertebrata
 walrus
 whales

RESOURCES:

American Cetacean Society
 "The Whalewatcher"
 P. O. Box 4416
 San Pedro, CA 90731

Earth Art Works
 % Steve King
 P. O. Box 5
 Alameda, CA 94501
 phone (415) 769-8500

General Whale
 % Larry Foster
 P. O. Box Save the Whale
 Alameda, CA 94501
 phone (415) 865-5550

Greenpeace Foundation
 2623 West 4th Ave.
 Vancouver, B. C.
 phone (604) 736-0321

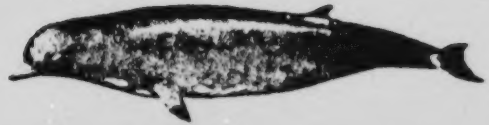
Defenders of Wildlife
 "There's a Sound in the Sea"
 A filmscript and teacher's resource
 unit on whales.
 1244 Nineteenth Street N. W.
 Washington, D.C. 20036

Colored Chart
 "Marine Mammals of the Western
 Hemisphere"

Superintendent of Documents
 U.S. Government Printing Office
 Washington, C.C. 20402

Stock No. 003-020-00106-8
 U.S. Govt. Printing 1975, 653-059

MARINE MAMMALS



Mammals? What makes an animal a mammal? If we look at the scheme developed by taxonomists to classify animals we see that the Phylum Chordata is at the top of the developmental list and that the subphylum Vertebrata is the most developed subphylum within the chordates. The most developed class is the Class Mammalia. Hmmm... Could it be just coincidence that taxonomists have placed man in the most developed class of the most developed subphylum of the most developed phylum? I don't suppose it could have anything to do with the fact that man made up the whole system. Interesting coincidence.

Back to the problem at hand. What are the characteristics that cause taxonomists to place an animal in the Class Mammalia? All mammals share two characteristics. First, all mammals have hair, sometimes the hair is not very evident, and in some of the whales, the hair is completely absent after birth. Second, all species of mammals feed their young with milk, a fluid secreted from special glands in the skin. These glands are called mammary glands.

In addition to these two distinctive characteristics, taxonomists often use others to help them classify an animal as a mammal. The hearts of all adult mammals have two ventricles - muscular, thick-walled pumping chambers. Also mammals are usually "warm-blooded", they are able to maintain

their bodies at a specific temperature regardless of the temperature of their environment. Further, most mammals have a means of nourishing the young within the body of the mother during the early stages of development.

1. What are the two characteristics that all mammals share?

In spite of the many characteristics they have in common, mammals show great diversity. The modifications of form that account for the diversity enable an organism to live in a particular niche. These modifications are called structural adaptations. What are the special structural and behavioral adaptations possessed by those mammals that spend their life in the sea?

2. Pressure is an environmental factor with which animals living in the seas must deal. What is one other environmental factor for which we might expect to see special adaptations possessed by marine mammals?

Marine mammals include whales, dolphins, porpoises, seals, sea lions, walruses, and sea otters. The bodies of marine mammals are well adapted for life in the sea. Most are streamlined, making it easier for them to move through the water. Seals' limbs are modified to form flippers, while sea otters have flipper-like hind feet. Instead of vertical tails like fishes, whales have horizontal tails--an adaptation that enables them to dive and surface easily. Whales combat

cold ocean waters by insulating their bodies with a thick layer of fat (blubber), which also provides buoyancy, padding, and a source of energy when food is scarce. Sea otters depend on long, fine, thick coats of hair for warmth. Seals have both a layer of fat and a coat of hair to keep them warm.



walrus

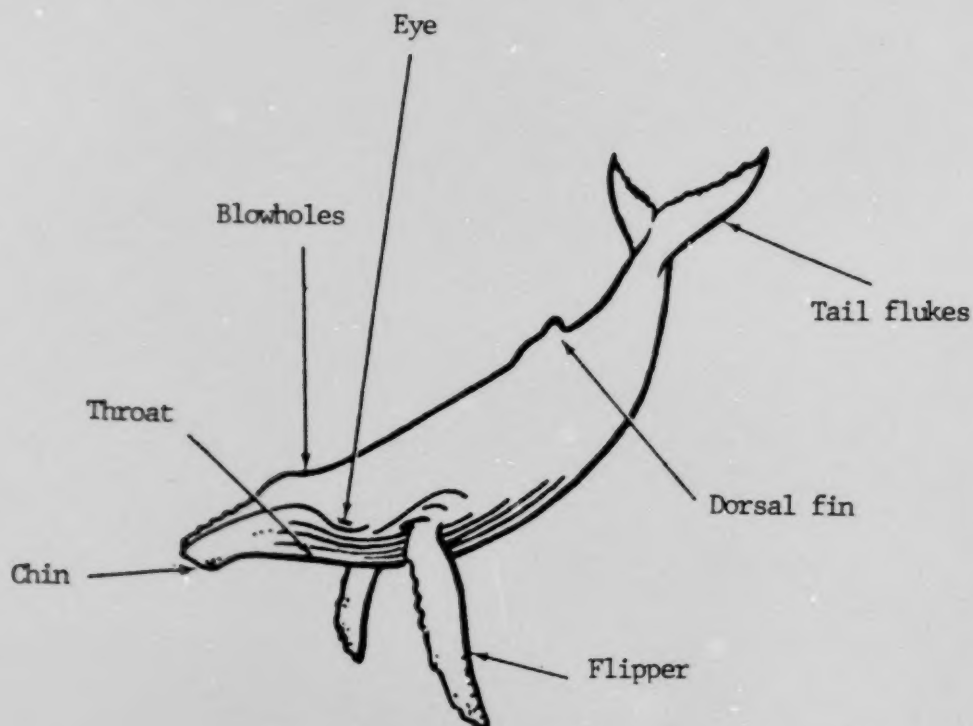
3. What are two ways in which marine mammals deal with the cold temperatures found in the seas?
 - a.
 - b.

Young marine mammals are born well developed and with their eyes open. The high protein and fat content of the milk of marine mammals puts fat on the young quickly, giving them needed insulation from the cold and providing energy for life functions. The young grow fast and can take care of themselves early in life, adaptations essential to survival in the marine environment.

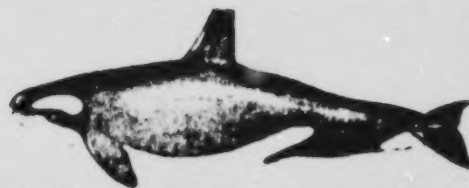


Marine mammals are unique in many ways. Perhaps the most fascinating aspect of marine mammals, especially whales, is their ability to dive deep and stay down a long time. Although, proportionally, their lungs are not much larger in size than those of land mammals, sperm whales can dive to depths of 3,000 feet and stay down for as long as 90 minutes.

4. What is one way in which the whale's ability to dive deep and stay down a long time help guarantee the survival of the whale?



Whales and Dolphins - The Cetaceans



Whales and dolphins have always caught the fancy of man because of their size, beauty, and playfulness. They have been valuable to man for centuries as a source of food and oil. The scientific name of the order, Cetacea, comes from cetus, the early Greek and Latin word for whale.

Cetaceans have poor senses of smell and of taste, but good senses of vision and an excellent sense of hearing. Whales and dolphins are apparently very intelligent mammals that make a variety of sounds, both for "talking" with one another and, in some cases, for use as a sort of sonar to locate food and avoid underwater objects.

Cetaceans breathe through nostrils (blowholes) on top of the head.

5. While most people would agree with Dr. Gornall's statements about man's encroaching on marine mammals, many would be skeptical about his saying that "the chirping of sea mammals is saying something is wrong".

Mammals' sea chirps could be warnings

PULLMAN — (AP) — Dolphins, whales and other marine mammals have something to say, but no one is listening, a marine biologist says.

Dr. Tag Gornall of Seattle says dolphins and whales are "chirping" off the Washington and Oregon coasts — and they're saying something is wrong.

Gornall likened the chirp of the dolphin and whale to that of the miner's canary. The birds once were used by coal miners to warn of foul air.

"Well, our aquatic animals are chirping right now. There's something wrong out there in the ocean," he said. He was at Washington State University this week to discuss the plight of marine animals.

The veterinarian said man has been encroaching on marine mammals for years and that man's growing population is further threatening the denizens of the deep.

"Pollution of the oceans is a gigantic problem, but we can't shake our fingers just at the oil industries or the steel industries," he said.

"In addition, all our individual acts — the dumping of oil off a small boat, the pumping of bilges into the water — come together to cause one big pollution problem."

Gornall said more than 600 mammals a year are being found stranded along the coasts of Washington and Oregon.

Seattle Times - May 20, 1980

In the space below, design an experiment that would provide information to either prove or disprove Dr. Gornall's hypothesis that the sea chirps are warnings.

Cetaceans usually give birth to only one off-spring each year. The young are large at birth, usually one-fourth to one-third or more the length of the mother. For example, an 80-foot blue whale may give birth to a baby that is 25 feet long and weighs 2 tons or more. The young grow fast, doubling their length within the first year. The cetaceans are divided into two groups:

1. toothed whales--dolphins, porpoises, beaked whales, sperm whales and pygmy sperm whales; and



Common dolphin

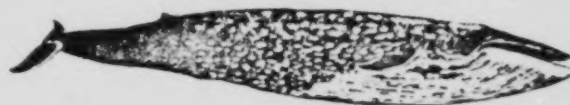


Harbor porpoise

2. baleen whales--blue whales, right whales, fin whales, and California gray whales.

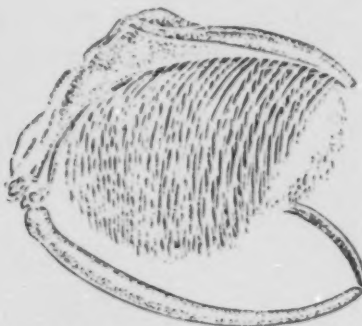


Northern right whale



Blue whale

Toothed whales feed mostly on fishes, squids, octopi, and occasionally on large mammals. Baleen whales have no teeth; instead, sheets of a fringed, fingernail-like material, called whalebone or baleen, hang from their upper jaws. Baleen whales feed on plankton, strained through the baleen, and also on small fishes and shrimp.



Whale baleen

6. Use the drawing of the whale's baleen to help you trace, in words, the path of plankton from free floating to swallowed!

Dolphin and porpoise are terms that often cause confusion. Strictly speaking, the long-beaked forms are called dolphins and the small, snubby-nosed forms are called porpoises. However, these words are commonly used interchangeably. The dolphin fish, also called mahi-mahi, is not a mammal.



Harbor porpoise

Eastern Pacific spotted
dolphin

7. Label the dolphin and the porpoise shown above. Use the information in the text to help you distinguish the two marine mammals.

Dolphins are perhaps the most popular cetacean with mariners. One reason is the human-like interest they take in play. They can be seen running at the bow of a boat or riding waves in the surf. Dolphins also show concern for one another--when one member of a group is injured, the others will come to its aid.

Whales are the largest animals known. In fact, the blue whale, reaching a length of 100 feet and a weight of more than 100 tons, is the largest animal that has ever lived. Larger than the largest dinosaur, whales can grow so large because their body weight is supported by the water and, in the case of baleen whales, because of the

abundance of the planktonic organisms on which they feed. Not all whales are large, however. Some, like the pygmy sperm whale, reach a length of only 13 feet.

Indian whale hunting goes back many centuries before the appearance of western man. Non-Indian whaling, the commercial fishing of whales for food and by-products, has also been carried on for many centuries. Whaling began off the East Coast of North America almost coincidentally with the first settlements. By 1640, there was a well established shore whale fishing on the East Coast. By the 1800's whalers from New Bedford and Nantucket, Massachusetts were plying the waters of the west coast in search of the whale. At that time, the main products taken were oil and spermaceti (a wax-like substance) used in lamps and for making candles, and whalebone, used in women's garments. Today whale oil is used in the manufacture of soap, cosmetics, shortening, lubricants, and many other products. The meat and rest of the body are used for human or animal food and for fertilizer. Ambergris--a rare, soft, grayish material found in the digestive tract--is the most valuable product from whales, and is used in the finest perfumes.

8. There are now substitutes for all of the products derived from whales. In your opinion, what is one reason that whaling continues?

Man's toll on whales has been so heavy that some species, including the blue whale, now are regarded as endangered. Whaling ended in the United States in 1971 when a law was passed protecting eight species of whales. Although international regulations have been set, enforcement has been ineffective. Great controversy now surrounds marine mammal harvesting. You will have a chance to explore some of the issues in subsequent activities.

Seals, Sea Lions, and Walruses - The Pinnipeds

Like the whales and other cetaceans, pinnipeds - the seals, sea lions, and walruses--are well adapted for life in the sea. The name pinniped: which means featherfeet, refers to the modification of the front and hind feet to form flippers. These flippers allow many of the pinnipeds to be excellent swimmers. Some pinnipeds, such as the harbor seal, may spend 6 to 8 months at sea, without ever touching land during that time. Others, such as the northern fur seal, spend considerable time on land. Pinnipeds have thick hides with heavy layers of fat underneath and, in some cases, fur to protect them from the cold. Pinnipeds may be separated into two groups:

- a. the eared seals including fur seals and sea lions
- b. the hair seals, or so-called true seals, including harbor seals, ribbon seals and elephant seals.





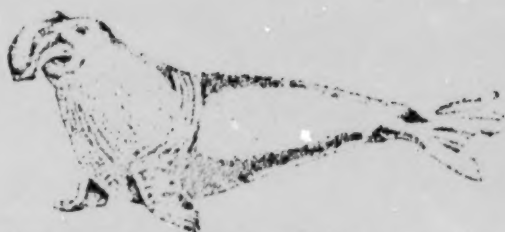
California Sea Lion



Steller Sea Lion



Harbor Seal



Northern Elephant Seal

EARED SEALS

HAIR SEALS

Eared seals have small, external ear flaps. They can turn the hind flipper forward, enabling them to move rapidly on land, and they use large front flippers for swimming. Eared seals breed in special areas called rookeries, commonly on offshore islands, to which they may return year after year. During the breeding season, males fight for territories on these rookeries, and victorious males hold groups of 20 or more females, called harems. Males may go more than 2 months without feeding during breeding time.



Fur seal

Sea lions are often seen along the coast. The trained seals commonly seen in circuses are California sea lions. Although the general public views them as interesting and appealing wild animals, commercial fishermen consider sea lions to be nuisances. Sea lions eat tons of fish, destroy valuable fishing gear, and interfere with fishing operations. As a result, quite a controversy exists over the value of sea lions.

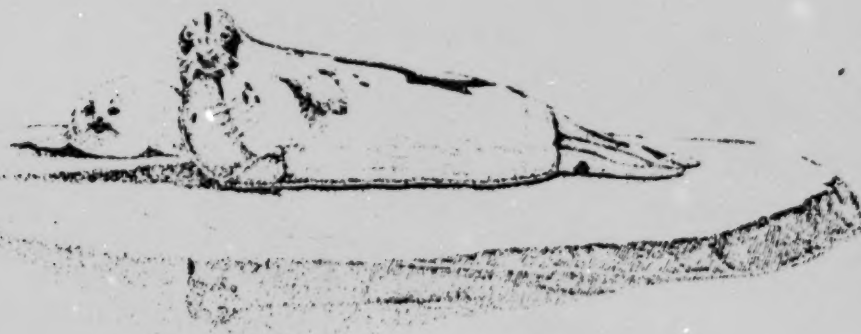
9. Fishers commonly blame marine mammals for reduced fish catches. What are two other factors that might be more important causes of reduced fish catches?

a.

b.

Hair seals have no external ears. Unlike eared seals, they cannot turn their hind flippers forward. They are consequently clumsy on land, only able to worm their way along. Hair seals have smaller front flippers than do eared seals, and primarily use their hind, rather than front, flippers for swimming.

10. Eared seals and hair seals differ in their ability to turn the hind flipper forward. Use these differences to decide which group of seals spends more time on land. Write your choice in the space below.



Harp seal

The Harp Seal is a "true seal" found in large numbers in the Arctic during the summer. Adult harp seals are sleek and silvery with a dark horse-shoe shaped patch on their backs. During the first three weeks of life, baby seals have soft, pure white fur. Because of the beauty of their coats, baby harp seals have been hunted for over a century. Controversy now rages between the seal hunters

and those opposed to seal hunting. Population estimates show drastic decreases in the numbers of harp seals from a historic figure of perhaps 15,000,000 to a current low of less than 2,000,000. As the debate over causes of the decrease continues, the hunting goes on. You will have an opportunity to look at this issue in more detail later.

11. The current population size estimate for harp seals is only _____ per cent of the historic figure. (Hint: This is easy.)

$$\text{percent of historic figure} = \frac{\text{current population estimate}}{\text{historic population estimate}} \times 100)$$

Sea Otter



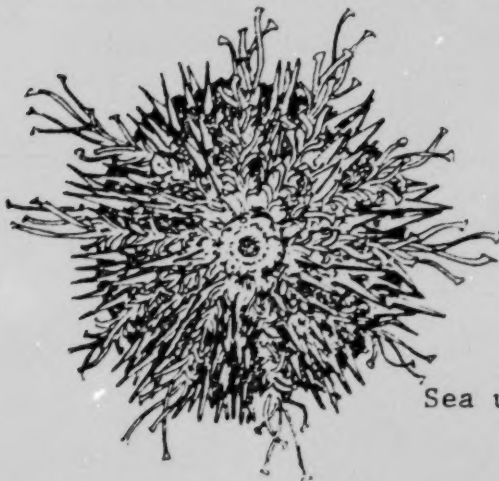
The sea otter is a member of the weasel family. Sea otters are closely related to river otters, but are considerably larger, often reaching lengths of 4½ feet and weights of 70 to 80 pounds. Their front paws, used for holding food and other objects, are stubby and rounded. The hind feet are large and webbed and, along with the tail, are slightly flattened for use in swimming. When moving rapidly, sea otters swim on their bellies. Otherwise, they are normally seen swimming or resting on their backs. They can dive to 300 feet and remain underwater 4 to 5 minutes to hunt for food.



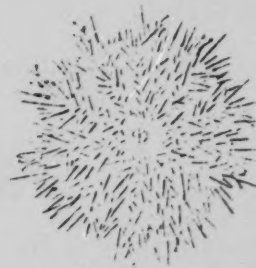
Sea otter

12. The sea otter for its body size has a lung capacity roughly proportional to ours. Use a watch with a second hand to determine how long you can hold your breath. Record the figure here: _____ seconds. How does your time compare with that of the sea otter? _____. For what percentage of the sea otter's time could you hold your breath? (Hint: use the same technique you used in number 11).

Sea otters eat sea urchins, mussels, crabs, turban snails, and a variety of other foods, although they rarely eat fish. They commonly are seen floating on their backs, banging open mussels and other shellfish against rocks held on their chests.



Sea urchins



Kelp

Since sea otters lack a layer of blubber, they depend on their fur and on food to maintain body heat. Indeed, an adult male easily can eat 15 pounds of food a day, nearly one-fourth of its body weight.

13. If the sea otter populations were reduced in number by hunting, what would probably happen to sea urchin populations?

14. Sea urchins eat kelp. What would likely happen to kelp beds if sea otters were reduced in number by hunting?
15. If you were a kelp harvester (remember all of those things we use algae for?), would you want to encourage or discourage sea otter population growth? Why?

Sleeping at night and feeding during the day, sea otters live in kelp beds, gathering in rafts (groups) of four or more animals. They stay close to the shore, but almost never come on land. Sea otters once ranged along the California coast wherever there were kelp beds. Because of their beautiful soft, dense, reddish-brown fur, sea otters were once the world's most valuable furbearer. At one time, the fur trade was the most important industry on the California coast. The total California sea otter kill from 1786 to 1868 was estimated at more than 200,000. By 1900, sea otters were generally regarded as extinct along the California coast, although a small group was known to exist near Point Sur. In 1911, the Fur Seal Treaty, protecting both fur seals and sea otters, was ratified by the United States, Russia, Japan, and Great Britain. This treaty, supplemented by rigid federal and state laws, has stopped harvesters

of sea otters, except for an occasional poacher or vandal. Stiff penalties exist for taking or possessing a sea otter or its skin. In recent years, populations have been increasing and otters have been expanding into new territories.

16. In the last few decades, scientists have noticed an increase in the number of purple urchins and widespread destruction of the kelp beds. In view of your answers to questions 13 - 15, would these results have been a predictable outcome of widespread sea otter hunting? Please explain your answer.

Much to the distress of abalone fishers, sea otters also eat abalone. In some areas off the coast of California, the California Department of Fish and Game has captured offending sea otters and moved them to reduce the abalone industry's loss. This plan has met with mixed success. Some otters transplanted 45 miles have returned to the point of capture within two months.

Sea otters breed and give birth throughout the year. Birth apparently takes place in the water. Since pregnancy lasts 8 or 9 months and a female has only one pup every 2 years, population increase is slow. In spite of this low reproductive rate, the sea otter population has been expanding. As expansion occurs, increased confrontations with abalone fishers are likely. It seems unlikely that sea otters will ever regain their former numbers.

17. In the debate over sea otters, abalone fishers and kelp harvesters are on different sides. Which side wins your support? Please explain why.

TEACHER BACKGROUND - Bradycardia - The Diving Response

The ability of marine mammals to dive for very long periods of time has fascinated man for ages. Large lung capacity seemed to be the obvious answer. Examination of marine mammals, however showed that marine mammals have lungs which are not significantly larger in proportion to body size than ours. By the turn of the century physiologists were looking for better explanations. After many ingenious experiments, it appears that diving mammals have a sophisticated system for reducing the heartbeat (bradycardia) while simultaneously reducing circulation to the peripheral body parts. Circulation to the brain and heart is maintained during the dives. Additional energy is derived during diving through lactic acid production. The lactic acid production causes an "oxygen debt" that must be paid when oxygen becomes available. The oxygen debts were found to be less than anticipated and evidence seems to indicate that there is also a reduction in metabolic activity in the non-active tissues deprived of oxygen. An interesting overview of the research is found in the following article which is recommended to you and to your students:

Scholander, P. F. "The Master Switch of Life", in Scientific American (December, 1963).

The following activity investigates bradycardia in man. Human divers appear to respond like other vertebrates when subjected to asphyxiation. Divers develop bradycardia within 20 to 30 seconds. There may be a difference between man and other vertebrates that merits mention: pathological arrhythmias, or irregularities of the heartbeat, are alarmingly common in man after only half a minute's dive and such arrhythmias have so far not been observed in animals. While adverse reactions are unlikely to occur in your class, be certain to caution your students to stop if they feel faint or uncomfortable. Also be certain that your students follow the directions as written.

Demonstrate the proper techniques for taking the pulse. The radial pulse may be taken by placing the first three fingers in the

hollow on the thumb side of the ventral surface of the wrist. Since the thumb has a pulse of its own, its use to sense other pulses is not recommended. The pulse may also be taken by placing the first three fingers on the Adam's apple and rolling them dorsally and anteriorly (back and up) into the depression of the neck where the carotid artery is located. While measuring the carotid pulse has some obvious disadvantages in this procedure, it is a stronger pulse and may be used where there is great difficulty in locating the radial pulse.

Duplicate the activity pages. One set is recommended per student. It is likely to take your students several trials before they are comfortable while immersing their face. Expect some general confusion during this period. The two minutes of strenuous exercise also can result in some noise and confusion. Be aware of these potentialities and plan accordingly. Caution your students to wipe up any spills as soon as they occur. This is an interesting and fun experiment when conducted under reasonable control. Upon completion, plan to allow time for a discussion of the text questions and the results.

KEY

Test Questions

1. Asphyxia is a condition in which too little oxygen is supplied to the living tissues.
2. The brain and heart tissues are most susceptible to damage from asphyxiation.
3. Bradycardia is a slowing of the heart action.
4. Diving animals avoid brain and heart damage during diving by:
 - a. bradycardia
 - b. reducing peripheral circulation while maintaining circulation to the heart and brain.

Analysis and Interpretation

1. The data shown on the bar graph should reflect that shown in the "Average rate/minute" column of the data chart.
2. Most likely the heartbeat rate will fall within the normal ranges shown. Averages are, however, just that and you will likely have students that fall without the averages. Allay their fears and assure them that their rates are appropriate for them!
- 3, 4, 5, 6, 7. Answers depend upon experimental results. In general, the effects of bradycardia are less pronounced if a subject is merely told to hold his breath without submerging his face.
8. Your students are likely to devise ingenious ways to measure a reduction in peripheral circulation. One of the simplest involves placing a blood pressure cuff around the calf muscle and inflating the cuff to the point of constriction of the venous or arterial circulation. The pressure is then reduced to the point where the blood just begins to flow and the subject's face is emerged. If there is a reduction in flow, it will manifest itself by a cessation in the fluctuations in the mercury column of the sphygmomanometer.
9. While the answer depends upon the experimental observations, there is no doubt that man does exhibit bradycardia when faced with asphyxiation.

KEY WORDS

asphyxia
 average
 bradycardia
 carbon dioxide
 circulation
 conclusion
 heartbeat
 oxygen
 peripheral
 physiological
 psychological
 pulse
 submerge
 suffocation
 strenuously
 susceptible
 tourniquet
 variation

BRADYCARDIA



Bradycardia - The Diving Response

Breathing and heartbeat mean life. These processes bring oxygen to our tissues and remove carbon dioxide. Any interruption of breathing or circulation threatens life. Interestingly enough, not all of the tissues of an animal need to be continuously supplied with fresh oxygen. Most parts of the human body display a considerable tolerance for asphyxia (too little oxygen). The tissues of an arm or leg can be isolated by a tight tourniquet for more than an hour without damage. The kidney can survive without circulation for a similar period. A transplanted cornea can survive for many hours. The heart and brain, however, are extremely sensitive to asphyxia. Suffocation or heart failure kills a human being within a few minutes, and the brain suffers irreversible damage if its circulation ceases for more than five minutes.

1. What is asphyxia?
2. Which tissues are most susceptible to damage from asphyxiation?

How do marine mammals avoid these problems during their very long dives? The simplest explanation would be that the diving animals have a large capacity for storing oxygen. When we look, we find that their lungs are not unusually large. Scientists have found, however, that every diving animal studied exhibits bradycardia, a slowing of the heart action when the animal is submerged. In addition to slowing their heartbeat, diving animals also close down circulation to most body parts while maintaining circulation to the heart and brain when making a dive. Typically, the blood supply to the muscles, intestines, and lower parts of the body is greatly reduced during diving.

3. What is bradycardia?
4. What are two ways in which diving animals avoid brain and heart damage during diving?

Do we observe bradycardia in man? In the following experiment you will have a chance to see if humans show the same diving responses as marine animals.

Materials:

dish pan

towels

cold tap water

stopwatch or watch with a second hand

Procedure:

1. Work in pairs. Record all data as you collect it on the data chart. Sit quietly for two minutes. During this time your partner can practice taking your pulse. After the two minute rest, have your partner count the pulse for 15 seconds. Multiply this number by four to find the number of heart beats per minute and RECORD this figure on your chart. Repeat the above twice more and determine the average for the three trials.
2. Exercise strenuously for two minutes (run in place, push-ups, situps, jumping jacks). Have your partner determine your pulse immediately. Record the beats per minute on the data chart. Repeat step two twice more and determine the average rate for the three trials.
3. Rest for two minutes.
4. After the rest, practice holding your breath for 35 second periods without activity. Rest for one minute between trials.

5. While holding your breath for 35 seconds, have your partner count your pulse the last 15 seconds of the 35 second period. Rest and repeat twice more and determine the average of three times.
6. Practice holding your breath with your face in the pan of cold water for 35 seconds. Submerge your face up to your ears. Have towels ready. When you have your self-confidence established and can do it without excitement you are ready for the next test.
7. With your face in the water up to your ears, have your pulse measured the last 15 seconds of the 35 second period. Repeat twice more and determine an average for the three times as before.
8. Empty and rinse the pan when finished. Assist your partner, repeat the experiment and collect her data.
9. Clean up the counters, floor, sinks, and spread the towels out to dry.

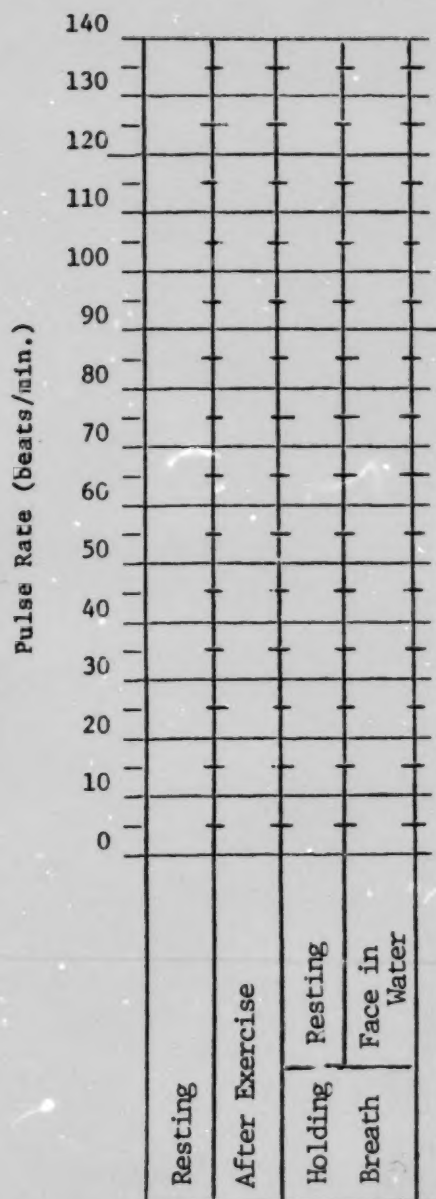
Analysis and Interpretation:

1. Complete the data chart by recording the average rates/minute on the pulse rate bar graph.
2. How does your seated (resting) pulse rate compare with the "Average Normal Variation in Heart Rate" shown on the data chart?
3. What was the effect of breath holding on your pulse rate?
4. How did placing your face in the water effect your pulse rate?
5. A reduction of pulse rate from the average range to 50 per minute is said to be bradycardia. Under which conditions did you show bradycardia?
6. Researchers have noticed that psychological factors tend to influence the physiological response to asphyxia. Under which condition did you worry most about suffocating?
7. Did the condition with the greatest fear of suffocating show a greater or a lesser degree of bradycardia?
8. In diving animals, bradycardia is usually associated with a reduction in circulation to peripheral body parts (parts other than the brain or heart). Design an experiment that would provide us with information to decide whether man shows a similar reduction in circulation.

9. From your observations would you conclude that man exhibits bradycardia when faced with asphyxiation? Which of the data you collected supports your answer?

DATA CHART:

Position & Activity	Pulse Count				Average rate/min.
	1st	2nd	3rd	Average	
Seated (resting)					
Seated (after exercise)					
Holding breath-(seated & normal)					
(seated with Holding breath- face in water)					

BAR GRAPH:Average Normal Variation in Heart Rate

Children: 72-92

Adults: 65-80

Women 70-80

Men 65-70

From a normal of 70 the pulse of a man after a 100 meter dash might be about 120.

Less than 50 is said to be

"bradycardia"

More than 110 is said to be

"tachycardia"

TEACHER BACKGROUND - Exploiting Marine Mammals and One Step Further...
and More One Step Further...

Marine mammal harvesting is surrounded by controversy. The activity "Exploiting Marine Mammals" and the two corollary activities which follow it explore some of the facets of the controversy. Man's record of dealing with marine mammals is not pretty. Traditionally interaction has caused the demise of the selected marine mammal species. "Exploiting Marine Mammals" contains three major sections. The first deals with the doctrine of "freedom of the seas" and the resultant tendency for nations to overexploit marine resources because of the "common goods problem" which was treated earlier in connection with Indian fishing rights controversies. Part two is a case study of whaling. The controversies surrounding whaling are a function of the common goods problem in the sense that since no one person or nation is guaranteed a return for wise management, there is no incentive to manage wisely. It is to the individual's best short-term interest to harvest as many whales as possible. The section deals with the apparent failure of the International Whaling Commission to regulate whaling. The Commission has the mandate to manage and regulate whale harvest but little or no enforcement power. The frustrations of this arrangement are treated in Part II "Whaling: A Case Study". The third major section is a case study of the Northern Fur Seal. This section shows the potential benefit from international cooperation in marine mammal management and contrasts the fur seal situation with that obtained in whaling.

Following the "Teacher Background" section you will find two groups of slides. Slides number 125 to 128 show whaling scenes while slides 129 through 136 depict sealing scenes. The following descriptions may be used as a commentary. There are alternative uses to consider before you decide on a final approach. You may choose to show the slides with no narration. Following the slides have your students react to the slides. Do the slides depict the inhumane treatment of helpless animals or simply the harvesting of a valuable crop? The slides may also be used as a preview, with or without

comment, of the material contained in this activity. The slides have also been effectively used as independent or small group study material. These slides should be augmented with other available audio-visual materials.

Commentary:

Slide 125 - A dead sperm whale being slaughtered off the Azores. The legendary Moby Dick belonged to this species.

Slide 126 - This slide shows the modern variation of the steam powered harpoon gun invented by Captain Foyen in 1862.

Slide 127 - A harpooned whale in flight.

Slide 128 - A harpooned whale is being pumped full of compressed air to keep it afloat until it can be pulled aboard the factory ship.

Slide 129 - A group of fur seals on Pribilof Island.

Slide 130 - This is a young Canadian harp seal. The Canadian government permits pups to be harvested by hunters.

Slide 131 - A fur seal cow in the act of protecting her pup.

Slides 132 and 133 - Two harp seal mothers standing beside their dead pups.

Slide 134 - This slide shows the primitive method used by the natives to kill the fur seals.

Slide 135 - In the background can be seen a group of fur seals recently harvested laid out in a line to be processed.

Slide 136 - A Canadian harp seal hunter standing next to his catch.

The nature of an ongoing controversy is that there are no hard and fast answers to provide to your students. The issues need to be discussed and developed. Unfortunately, the discussion does not provide the solution. "One Step Further..." provides some concrete ways in which to approach this dilemma. The following questions can provide material for group or class inquiry discussion sessions:

1. What do you feel is the future of the remaining whales?
2. What might have happened if the whaling nations had cooperated with one another and established realistic quotas and regulations?

3. Do you think that fixed proportions of whales could have been harvested each year? What benefits would have been guaranteed to the people of the world by doing that?
4. Based on our discussion at the end of the last class, what powers could have been given to the whaling commission to enforce its regulations?
5. How does the treatment of the seal differ from that of the whale?
6. Why can nations agree to protect one but not the other?
7. What had to take place before the nations would act to protect the seal?
8. Could the revenue sharing concept be adopted by the whalers?

Encourage your students to become involved in the efforts to reach a more sane management policy for marine mammals. "One Step Further..." gives some suggestions for ways to become active. "More One Step Further..." is included to provide encouragement for your students' efforts. Collectively we can make a difference. Two excellent books to help you and your students become more involved are:

Friends of the Earth. 1978. The Whale Manual. Published by Friends of the Earth, San Francisco, New York, London. 156 pages.

The Center for Action on Endangered Species, Inc. 1978. The Whalebook by Whale Protection Fund, The Center for Environmental Education, Inc. Washington, D. C. 64 pages.

Duplicate the activity pages. One set is recommended per student. "Exploiting Marine Mammals" may be conveniently divided into two lessons. The first includes the text and questions through "Whales: A Case Study". The slides of whaling belong with this lesson. The second lesson includes "Northern Fur Seals: A Case Study" and the slides that depict sealing. "One Step Further..." may involve a lifetime of work. The lessons are best completed by individuals working at home or in class. After the text is read and the text questions are answered, encourage small group or class discussion of the questions included above. These materials allow for flexibility. Use the approach that will provide the most positive experience for your students.

KEY

1. The effect of modern technology has been to increase the total fish catch often to the point of destruction of the fish resource.
2. The two warning signs that indicate a marine mammal population is being over-exploited are a decline in the average size of the marine mammal of a given species that is taken and an increased intensity of the effort necessary to catch the same amount as harvested in previous years. In other words, more effort to catch smaller (often immature) individuals.
3. The right whales were slow and small enough to float after being killed. These attributes led to its extinction through overhunting.
4. The three technological breakthroughs which allowed whalers to hunt the large, fast-swimming great whales were the steam powered ship, the cannon fired harpoon with an explosive head, and the pumping of compressed air into the carcass to keep it afloat.
5. The construction of the first "factory ship" was a breakthrough for whale hunters because it allowed them to pursue and kill whales on the open seas while eliminating the need for hauling these pelagic kills to a shore station for processing.
6. The two major shortcomings that prevent the International Whaling Commission from being effective in whale management are:
 - a. Any member nation, if it gives 90 days notice can refuse to obey any Commission decision.
 - b. The Commission was powerless to regulate the number of factory ships or to allocate a quota to any of them.Essentially the problem lies with the lack of enforcement powers possessed by the IWC.
7.
 - a. The major increase in the number of Sei whales killed annually began in about 1958.
 - b. The catch of blue whales was decreasing during the years when the Sei whale catch was increasing.
 - c. It appears that whalers have maintained a constant total annual whale catch by substituting plentiful species for the species that were being destroyed. In this case, Sei whales were being substituted for blue whales.

- d. Since the end of the 1960's the annual catch of Sei whales has taken a drastic fall. Sei whales have obviously been overexploited and the whalers were forced to find a new species. Pity the poor Minke whale that appears next in line for destruction.
- 8. It was necessary to ban the killing of five species of whale in 1976 because the IWC had been unable to regulate whale harvest to provide for the survival of the whales. The whales were on the brink of extinction and a ban was the only hope for their survival.
- 9. A moratorium on all commercial whaling would allow the depleted stocks of whales to recover.
- 10. Non-native hunters valued the fur seals for the seal's fur coats which were made into fur coats for the hunters. Native hunters had used the seals for food and fuel as well as for clothing.
- 11. a. If you were certain that you would be given a second 20 year contract it would be to your benefit to manage the seals for a sustained yield. You would want to be able to make a reasonable income each year for the duration of your lease period.
- b. The picture changes, if you are sure you are not going to have your contract renewed. The incentive and economically wise thing to do in the non-renewal situation is to kill as many fur seals as you can lay your hands on during your last season in business. This question really presents a microcosm of the common goods problem. The lease holder with a long term lease is equivalent to a private owner - the incentive is for wise management. The short term lease holder is in the same situation as any participant in a common goods fishery. If he lets the seals go to breed next year, there is no guarantee that he will get to kill the seal next year. The incentive is to kill everything now. Shrewd economic management in this latter case spells disaster for the resource.

12. Protecting the seals on the breeding grounds proved to be an ineffective way to protect the species because of open sea sealing. Pelagic hunters killed the seals before they could reach the island refuges.
13. In return for their agreement not to hunt the seals on the open sea, Canada and Japan were each given 15% of the total revenue gained from the hides. In effect, these nations were paid not to hunt.
14. A similar situation might involve a cessation of whaling by all nations except for one (or perhaps one whaling company made up of individuals from all nations) regulated by the IWC. The total revenues would be divided among all of the current whaling nations in proportion to the intensity of their investment in whaling. This plan would allow all nations currently whaling to regain some of their investment in whaling equipment while eliminating their expenses and restricting the kill. Such a system would have obvious benefits for the whales.
15. Currently a whaling nation's income is determined by the intensity with which it hunts. The incentive is to take as many whales as you can today and worry about tomorrow, tomorrow. The philosophy of maximizing profit through maximizing kill spells doom for marine mammals.

KEY WORDS

annihilation

attributes

Basque

carcass

conservation

depleted

exploiting

extinction

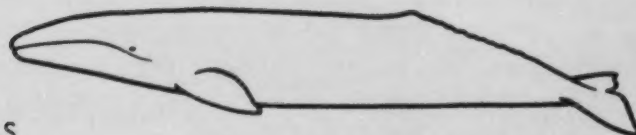
factory ship

Fur Seal Convention

gear
harpoon
harvest
International Whaling Commission
law of the seas
lease
marine mammals
moratorium
native
Northern Fur Seal
overexploitation
Pribilof Islands
processing ship
population
quota
regulation
slaughter
technological breakthrough
technology
treaty
whaling

12 SLIDES WERE REMOVED

#235 ECONOMIC & POLITICAL
EXPLOITATION



EXPLOITING MARINE MAMMALS

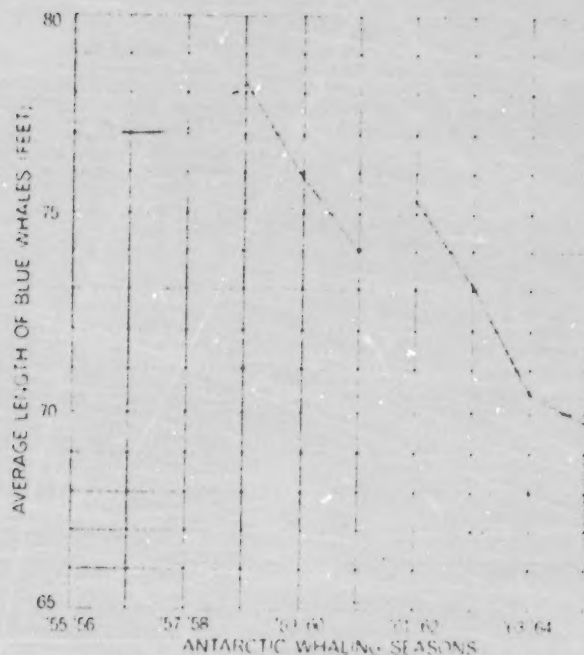
The nations of the world have for centuries refused to accept any restrictions or limitations on the quantity of fish that any one nation could catch. The international law of the seas provides for "complete freedom of the seas" outside accepted territorial waters. For most of the previous history this lack of catch restrictions is understandable. Both the size of the ships and the method used to catch marine mammals ensured the continuation of all the species. A ship would put to sea, catch as many as it could hold, and return to port to process and sell its catch. However, modern technology has provided whaling fleets complete with accompanying processing ships. Smaller ships catch their limits, transfer the whales to the processing ship, and return to chase the same school of whale if possible.

1. What has been the effect of modern technology on the total fish catch?

The extermination of a species occurs through what is technically called "overexploitation". The results of overexploitation vary from a slow decline in the abundance and availability of a species to an abrupt and permanent elimination.

In fishing and hunting, the usual signs of over-exploitation are a decline in the average size of the animal that is taken and an increase in the effort necessary to catch the same amount as harvested in previous years.

Overexploitation?



NINE-SEASON RECORD of the average length of blue whales killed in the Antarctic shows a decline that began in the 1959-1960 season. The average mature female is 77 feet long and a mature male 74 feet. Evidently recent catches have included immature whales.

The normal response to a declining marine species has been for the fleet to increase hunting time and energy, while making improvements in gear and methods.

2. What are the two warning signs that indicate a marine mammal population is being overexploited?

In most cases an attempt to revive the species by halting or limiting the size of the catch is not initiated.

Whaling: A Case Study

Commercial whaling began in the 12th century in the Bay of Biscay off northern Spain. Here a group of Spaniards called the Basques hunted the small, slow Biscayan Right Whale. It was named the "right" whale because it was small enough to float after it had been killed. The larger species of whale would sink and were therefore called the "wrong" whales. By the 13th century the Basques had established a precedent that would be continued for the next seven centuries - the Biscayan Right Whale had been hunted into extinction.

3. X Since the Basques hunted whales without the advantages of modern technology, what attributes of the whale allowed it to be hunted to extinction?



Part of the town seal of the Basque town of Biarritz in 1351 showing whaling in the Bay of Biscay.

By the 16th century the whalers of Europe had extended the hunt into the Atlantic off the coast of Great Britain and France. They pursued the species known as the Atlantic Right Whale. It was black in color, very abundant, and rich in oil. By the 17th century the Atlantic Right Whale was extinct.

The whaling fleets now moved further north into the waters around Iceland and Greenland. Here lived a species that was rich in the valuable whale products of baleen, oil, and meat. It was called the Greenland Right Whale and it too soon became extinct.

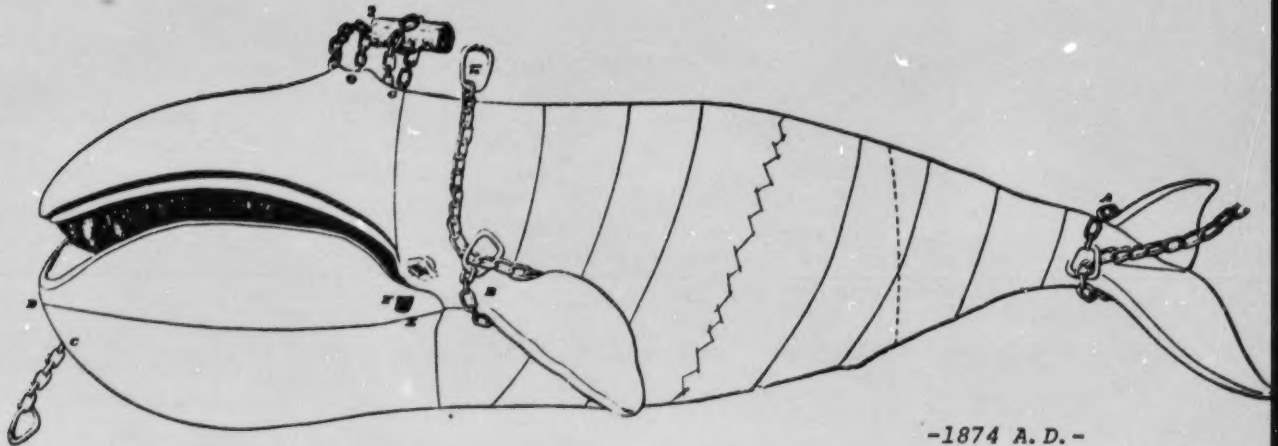


DIAGRAM SHOWING THE MANNER OF CUTTING - IN THE BOWHEAD AND RIGHT WHALE.

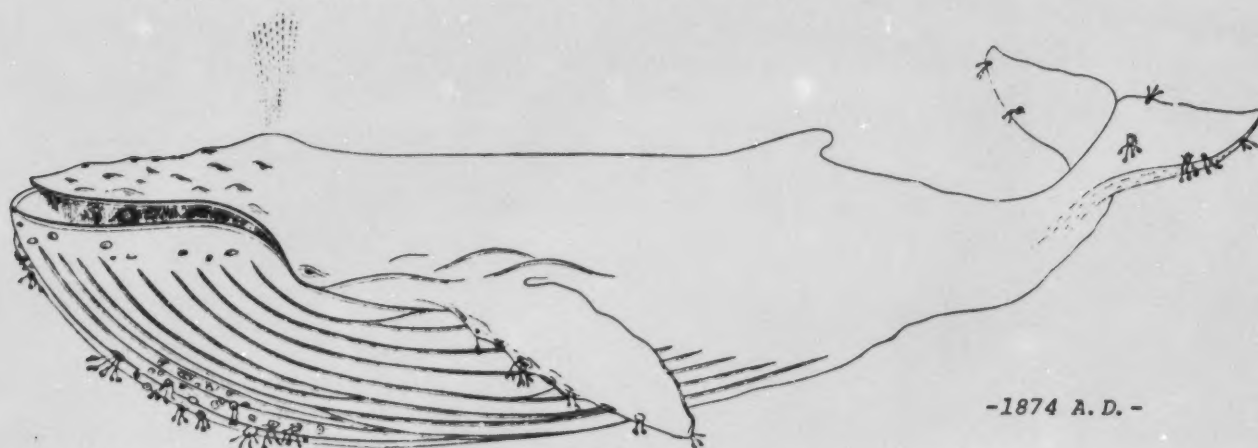
By the beginning of the 19th century the whalers of the North Atlantic were in serious trouble. The majority of small whales were now extinct; only the large, fast-swimming whales remained. Then in 1862 a Norwegian whaler named Svend Foyn developed a new method for hunting the big whales. He adapted the steam engine to his whaling ship and invented a cannon-fired harpoon with an explosive head. With this device he could now catch the faster whales. The problem of keeping these large whales afloat still remained. To solve this problem Foyn pumped compressed air into the carcass.

4. What three technological break throughs allowed whalers to hunt the large, fast-swimming great whales?

Armed with Foyn's new technique the North Atlantic whalers now attacked the large blue whale. The technique was so effective that by 1903 the blue whale was no longer found in the Northern Hemisphere.

Having destroyed their livelihood in the Northern Hemisphere, the whalers now turned to the great Antarctic summer feeding grounds. The first Norwegian fleets to sail in the Antarctic returned home with reports of whale herds of tremendous size.

The estimates of the first Norwegian fleet were accurate. The herds were so bountiful, it is estimated that 25% of the whales killed floated away before they could be skinned. The whalers refused to learn any lessons from their experiences in the North Atlantic. They picked the slowest species in the Antarctic region, the humpback whale, and hunted it mercilessly. In 1911, 8,500 humpback whales were killed; by 1925, only 9 humpback whales could be found to kill.



OUTLINES OF A HUMPBAC,

With special reference to its short and broad pectorals, and to the parasites, commonly called barnacles, which adhere to the throat, pectorals, and caudal fin.

As the whalers killed off the whales that bred near the Antarctic islands where their fleets anchored, they forced themselves to go out to sea to find whales. This would have been a very costly operation since it involved hauling the dead whales back to one of the islands to be processed. However, in 1925 a Norwegian captain constructed a large "factory" ship that could accompany the fleet out into the Antarctic Ocean. The ship had a slipway by which the whale was hauled onto the deck to be processed. The factory ships were so successful that by 1930 thirty-eight of them were in operation. These ships permitted the whaling nations to increase their catch from 10,500 in 1925 to 40,200 in 1931.

5. In what way was the construction of the first "factory ship" a breakthrough for the whale hunters?

In 1931, the first attempt to create international regulations for the whaling industry was initiated. This attempt was the Convention for the Regulation of Whaling. This agreement tried to protect the remaining "right" whales, immature whales, and females accompanied by a calf. Its effects were immediately doomed because two of the leading whaling nations, Germany and Japan, refused to sign it.

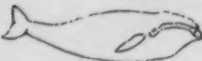
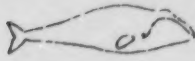
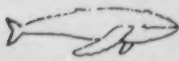
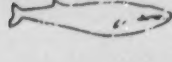
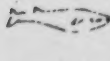
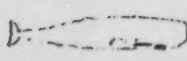
Following World War II a second attempt was made to establish controls due to predictions of many marine scientists that the whale would be annihilated if the pre-war slaughter continued. In 1946 in Washington, D.C. the International Whaling Commission was created. Most of the world's whaling nations joined the Commission. The Commission had the duty to set minimum-length requirements, set the opening and closing dates for the whaling season, and set an annual Antarctic quota.

Despite its impressive responsibilities the Commission was also doomed to the role of a powerless administrator. Any member nation, if it gave 90 days notice, could refuse to obey any Commission decision. Also the Commission was powerless to limit the number of factory ships or to allocate a quota to any of them. This would have violated the principle of the freedom of the high seas which grants to every nation the right to use the resources of the oceans as it decides. The result was an increasing number of whaling fleets hunting fewer and fewer whales!

6. What are two major shortcomings that prevent the International Whaling Commission from being effective in whale management?
 - a.
 - b.

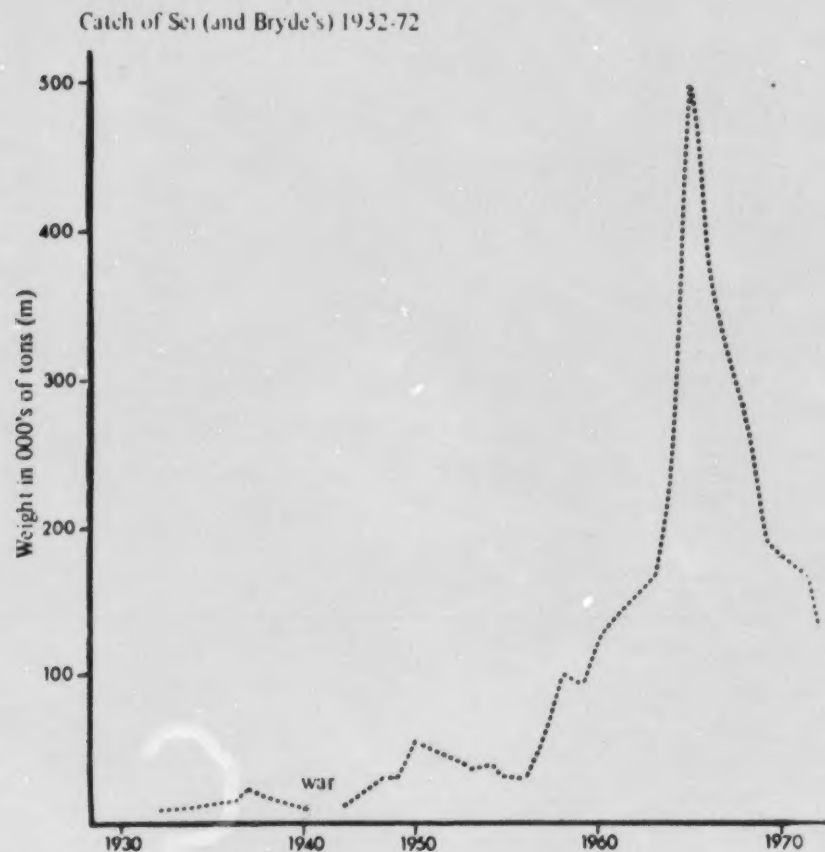
In the years since the creation of the International Whaling Commission, the estimated quantity of whales has continued to decrease. The necessity to make decisions based on the opinions of the member nations has resulted in protection for the various species of whales coming too little and too late. While scientists and annual catch statistics continually predicted that the blue whale would be hunted into extinction, the Japanese, Russian, and Dutch members refused to agree to any regulation to protect it. In 1964 the number of blue whales killed dropped to 20 for the entire whaling industry. This is compared with 29,400 killed in 1931.

The Great Whales

		LENGTH	CHARACTERISTICS HUNTING AND PROTECTIVE STATUS	ESTIMATED POPULATION	
				ORIGINAL	PRESENT
	RIGHT WHALE <i>Balaena glacialis</i>	to 58'	slow; buoyant; 40 percent blubber (up to 16" thick); a wartlike "bosses" on front of upper jaw; fully protected since 1935	50,000	3,500
	BOWHEAD WHALE <i>Balaena mysticetus</i>	50' to 60'	slow; buoyant; white chin; baleen to 14' long; not commercially hunted since 1912; fully protected since 1935	10,000	1,500 to 2,000
	HUMPBACK WHALE <i>Megaptera novaeangliae</i>	to 50'	walloped flippers almost one-third as long as its body; Antarctic hunt ended 1963-64; North Pacific hunt prohibited 1966	100,000	6,000
	BLUE WHALE <i>Balaenoptera musculus</i>	to 100'	also called sulphur-bottom; pygmy blue, a small subspecies; Antarctic hunt prohibited 1964-65; North Pacific hunt prohibited 1966	210,000	12,000 -half pygmy blues
	FINBACK WHALE <i>Balaenoptera physalus</i>	to 80'	formerly most abundant of all rorquals; fully protected since 1974 except in one Antarctic area until 1976, and around Iceland	470,000	105,000
	SEI WHALE <i>Balaenoptera borealis</i>	50' to 60'	today the most heavily hunted of all large baleen whales	205,000	90,000
	BRYDE'S WHALE <i>Balaenoptera edeni</i>	to 50'	virtually indistinguishable from the sei whale, but slightly smaller; IWC set zero quota on this species in 1976. (Catches by Japan and the Soviet Union have increased in last few years.)	100,000	40,000
	MINKE WHALE <i>Balaenoptera acutorostrata</i>	to 30'	also called little piked whale; white band across each flipper; not seriously hunted in Antarctic until 1972; now most heavily harvested baleen whale worldwide	560,000	300,000
	GRAY WHALE <i>Eschrichtius robustus</i>	to 45'	Atlantic and Korean races extinct; California stock reduced to a few hundreds by early 1900s; fully protected since 1917; Mexico made Scammon Lagoon a refuge for the species in 1972.	12,000	11,000
	SPERM WHALE <i>Physeter catodon</i>	to 60'	heavily hunted in 18th and 19th centuries and again following WW II; presently overhunted	870,000	500,000

Following the 1964 season the member nations agreed to place the blue whale on the protected species list. In effect the whaling industry had waited until the blue whale could no longer be hunted profitably before they would protect it!

7. The graph below shows the catch of Sei whales from 1932 to 1971. Use this information to answer the questions that follow the graph.



- In which year did the major increase in the annual catch of Sei whales begin?
- What was happening to the catch of blue whales during the years when the Sei whale catch was increasing?

- c. From this information, how does it appear that the whalers maintain a constant total whale catch?
- d. What has happened to the annual catch of Sei whales since the end of the 1960's?

In 1964 the Commission set a quota of 16,000 whales that could be killed. Scientists predicted then that the figure was too high and the whale population would not be able to recover. By 1963 the Committee of Three, a team of three scientists hired by the Commission to advise on the proper quota limit, suggested a limit of 4,000 whales. The Japanese refused to accept a quota of less than 10,000 whales. Since the Japanese could have refused to accept the Commission's quota, the rest of the nations on the Commission agreed to the Japanese figure. The Japanese refusal underscores the Commission's lack of enforcement power.

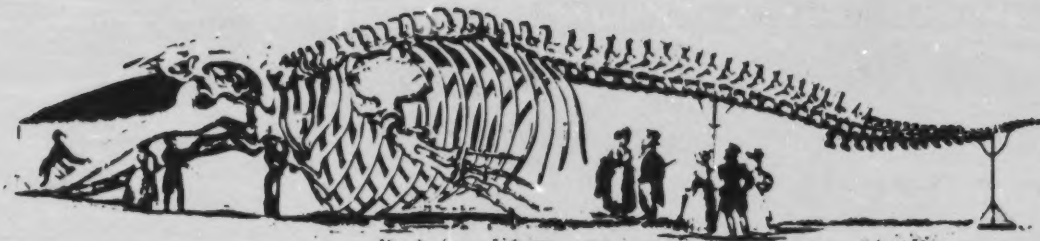
By 1976, thirty years after its foundation, it was abundantly clear that the Commission had still not fulfilled its obligations. In that year it was necessary to ban the killing of all Fin Whales in the Southern Hemisphere and North Pacific, Sei Whales in the Nova Scotia region of the North Atlantic and in two regions of the Antarctic, Bryde's Whales in the Southern Hemisphere, Minke Whales in the East and Central South Pacific, and Sperm Whales in areas of the Southern Hemisphere.

8. Why was it necessary to ban the killing of five species of whales in 1976?

Of the 150 member countries of the United Nations, only 17 belong to the IWC, so that approximately 90% of the UN nations have no part in the decisions of the Commission. If whales belong to anyone they belong to everyone and it is essential to the future survival of this planet that all peoples be consulted in the conservation of whales and all other things living in international waters.

Without the work of committed scientists, individuals and organizations from all parts of the world, the plight of the whale would probably be worse--if that is possible--than it now is. The tragedy of the whales is a failure of international cooperation.

Conservationists are calling for a moratorium ("ban") on all commercial whaling for a minimum of ten years to prevent the extinction of currently overexploited whale species, to allow the depleted stocks of whales to recover, and to give scientists time in which to make proper and accurate assessment of whale populations and their ecology. This moratorium coupled with a greater funding of non-destructive research could offer some whale species a chance to avoid extinction.



A mounted skeleton of a whale attracting the attention of the curious in 1837. Will this be all we can pass on to future generations?

9. How would a moratorium on all commercial whaling benefit the whales?

Northern Fur Seals: A Case Study

Off the coast of Alaska lies a chain of islands on which every year a mysterious chapter of nature repeats itself. Here the Northern Pacific fur seal herds arrive each summer to await the birth of the new members of their species.

The fur seal is a mammal which spends most of his life swimming in the ocean in search of food. The bull fur seals arrive on the island in May and prepare a stretch of beach for themselves and their 50 - 60 wives. The wives arrive in June. Soon after they arrive the pups are born. By August the pups are old enough to hunt and swim. In September the herd returns to the ocean and starts south to repeat a cycle which will end on the same island nine months later.



FUR SEAL

1 - Male 2 - Female

The islands are named the Pribilofs after the Russian navigator who discovered and claimed them in 1783. Pribilof was searching for the breeding grounds of the fur seals.

Pribilof wanted to find the seals because of the value of their skins, which were later made into expensive coats. The seals however, had been of value to the Eskimos for centuries because they were a source of food, fuel, and clothing.

10. Why were the fur seals valued by non-native hunters?

While under the control of Russia, the seals were killed by the millions. In 1867 the islands were bought along with Alaska by the United States. The slaughter of the seal did not stop however. The United States granted a 20-year contract to a private company in 1870, which permitted the slaughter to continue. In 1890 the contract was granted again to another company.



"Fur seals sporting around the baidar — Natives of St. Paul lightering off the bundled sealskins to the ship from the Village Cove." A sketch by Henry W. Elliott, who visited the Pribilofs for the Treasury Department and the Smithsonian Institution in 1872, shortly after purchase of the islands from Russia. The baidar, or bidarra, was made of sea lion skins, canvas-covered bidarrahs are still used in ship-to-shore ferrying.

11.a. Assume you are the president of Fur Seal Coats, Ltd. and are nearing the end of your 20 year lease period which gives you the right to kill fur seals in the Pribilofs. How would you regulate the number of fur seals killed by your hunters if you were sure you would be given a second 20 year contract?

b. How would you regulate your fur seal hunters if you were sure you would not be given a second 20 year contract?

It was during this period that the American government became concerned with the impending annihilation of the fur seal. It attempted to control the destruction on the Pribilofs.

However the destruction continued offshore where American, Russian, Canadian, and Japanese fishing boats would spear the seals as they approached the islands.

In 1892 the United States asked Great Britain and Japan for help in protecting the seals. They would agree only to suppress hunting within a 60-mile radius of the Pribilof Islands.

12. Why did protecting the seals on the breeding grounds prove to be an ineffective way to protect the species?

By 1911 a herd that once numbered in the millions had been reduced to 3,191 seals. The nations of the world at this point stepped in to protect what was left of the herd. On July 7, 1911, the North Pacific Sealing Convention was signed by the United States, Japan, Russia and Great Britain. Under the agreement, all open sea seal hunting was forbidden north of 30 degrees North latitude. Each nation which owned islands in the area was permitted to regulate hunting on it. The United States and Russia, who owned the islands concerned, agreed to share the revenue gained from the hides and to give Canada and Japan 15% of the total amount.

13. Since Japan and Canada owned no seal breeding islands, regulations limiting onshore hunting had little effect on them. What incentive was given to Canada and Japan to persuade them to stop open sea sealing?

Under international protection, the herd increased from 3,000 to 4,000,000 in half a century. From this four million, an annual harvest of 60,000 to 70,000 three year old males is taken.

The killing of the seals is done by the natives of the islands under the supervision of the United States government. The salaries paid by the government to the natives makes up their total income for the year. It should be noted that the methods used by the natives to kill the seals are primitive and considered by some to be inhuman. In spite of these charges few can deny that the protection afforded through international cooperation has saved the fur seals from a fate similar to that of the whales. The Northern fur seal case shows that it is possible for nations to work together to protect valuable marine resources. Hopefully, the lessons learned in this case study will be applied to other marine mammals as well.

14. The fur seal convention works because all of the nations that were sealing receive some portion of the total income earned from the reduced hunting allowed by the treaty. How could you create a similar situation involving whales and whaling nations?

15. Whaling regulations now do not guarantee any nation a fixed percentage of the total income from whaling. How is a nation's income determined?



ONE STEP FURTHER.....

What can you do? Despite the fact that whaling is an energy-intensive industry with diminishing returns; despite an international outcry against further slaughter of whales; despite scientific advice that whales are severely depleted from their initial levels; whaling continues. It continues because the whaling companies are still making money. The problem is immediate. Solve it. Do it. Share the planet.

The focus of most conservation action is to pressure the USSR and Japan, the two nations responsible for 82 - 84% of all great whales slaughtered. Here are the on-going campaigns which you can join.

Letters

Candid government officials will tell you they read and count letters, and they feel if one person actually takes the time to sit down and write, a thousand must be upset. A whale is killed about every 19 minutes. In the amount of time it would take to write a letter, another cetacean is gone.

The single most effective direct action is letter-writing. Do it. Get your friends and acquaintances to do it. One letter is worth many petitions. Make the letters short and to the point: ask for a moratorium; remind leaders that whales do not belong to one nation

or one company; protest the slaughter.

UN Mission: Japan
866 UN Plaza
New York, NY 10016

UN Mission: USSR
136 East 67th Street
New York, NY 10020

Embassy of Japan
2520 Massachusetts Ave. NW
Washington, DC 20008

Embassy of the USSR
1133 16th Street NW
Washington, DC 20003

Write also to our government to let it know of your concern. Each year a delegation from the US goes to the International Whaling Commission meetings. Many times a year trade negotiations are transacted. If our elected and appointed officials are aware of public concern for whaling, they can take the American point of view to these transactions.

Honorable Edmund Muskie
Secretary of State
Department of State
Washington, DC 20520

Richard A. Frank
Administrator
National Oceanic and
Atmospheric Administration
U.S. Department of Commerce
Washington, D. C. 20230

Personal Communications

Whale oil is still used in many parts of the world for many industrial processes. Margarine in Europe, for instance, contains whale oil. Leather dressings used in the United Kingdom and Italy, particularly, are sperm whale oil. Whale products are no longer used in the U.S. for any of these applications, so we know good substitutes exist.

We have to keep in mind that many countries do not have large, funded conservation groups. So, personal

communications with people in foreign countries is extremely helpful to publicize the plight of whales. Many people simply are not aware of the problem. Write to your friends abroad. Send them copies of our literature. Tell them of the immediacy of the problem. Urge them to help the conservation groups in their own countries.

If you do not know of a conservation group operating in a foreign country, tell your overseas friends to write to:

Friends of the Earth, Ltd.
9 Poland Street
London W1V 3DG, U.K.

FOE/London can give them information about conservation groups in their own country, and probably supply up-to-date information about the status of whale protection efforts in their country.

Plant a Bush: The Jojoba Project

Another wedge in the economics of whaling is provided by The Jojoba Project, which is organized to plant the desert shrub jojoba (ho-HO-ba), Simmondsia chinensis. Basically, the fruit of the long-lived, evergreen desert plant jojoba is the best known substitute for whale and sperm whale oil. The problem is, there is not enough of it. Harvested from wild plants in Arizona, California, and Mexico, jojoba oil can substitute for whale oil if it is available in sufficient quantity.

As petroleum stocks dwindle, additional pressure will

be brought on whales for use of their unique oils as lubricants for machinery. Jojoba oil is the best substitute; therefore, to relieve pressure on whales, we need to get jojoba planted.

The Jojoba Project is a simple plant-a-tree campaign. For \$1, a seedling can be planted in your name on lands owned and cultivated by native Americans in Arizona and California. Essentially, the \$1 pays for labor involved in planting and growing. It gets these seedlings into the ground, and helps reservation economy as well.

The Jojoba Project
Rosemary Elkins, Coordinator
JOJOBA, The Center for Action on Endangered Species, Inc.
P. O. Box 2749
Tucson, Arizona 85702

Distributing Materials

Conservation groups have materials to be distributed to the general public. An informed public is essential to the campaign to protect whales. Distributing these materials through the mail is costly, so any help you can give to get the word out to many people is important.

Don't overlook local events--flea markets, fairs, conferences, general meetings of the local bird and sport clubs, women's groups, garden clubs, etc. These are great places to set up a table, talk, and hand out information. Sometimes money can be raised at these functions, too.

Some people get a stack of brochures from the large conservation groups and simply tuck them in with letters they write to friends. It costs no more in postage, and gets information out.

See the Help the Helpers Section for addresses of conservation groups. Help them by distributing information.

Send Money

Despite various myths, most conservation groups have limited and sometimes inadequate funds. Most are tax deductible for Federal Income Tax purposes, so you help yourself as you help them. Save your quarters for a month and send it to a group working on whales. Give the whale champions a Christmas present. Celebrate your own birthday with a gift to whales.

Much of the in-fighting and negotiating on the whale problem goes on in symposia, meetings and conversations with regulatory agency people. Those people who are standing for the whales in these confrontations need funds for travel, salaries, researching the problem. And, publishing costs money--lots of it. Your contributions to groups really working on the whale problem are necessary and welcome. There is no free lunch.

Help the Helpers

These organizations, most of them tax-deductible, need your support to continue their efforts on behalf of cetaceans all over the world. Some people may wonder

why so many groups are working directly on the whale problem, or why these groups don't combine into one group. There isn't an easy answer, but there are some reasons. One, each group tends to reflect a particular segment of society, and while there are certainly overlaps, broader coverage of America's human population occurs as a result of the number of groups. Two, each group has a tone particular to it, which appeals to different members of society. Three, many groups focus on one or more issues, or spend their limited money in specific ways. (General Whale, for instance, produces graphics, posters, and works to correct the image of the whale, both physical and psychological; The Center for Action on Endangered Species works on jojoba and teaching tools; The Whale Protection Fund is maintaining a major petition drive; Friends of the Earth and Project Jonah are very active at a policy level; Animal Welfare Institute is a major source for boycott information.)

We apologize in advance for errors and omissions. The best way to find out what a particular group is doing is to write or call and ask. All of these groups are contributing to the global effort to stop the needless slaughter of whales. They need and deserve your support.

AMERICAN CETACEAN SOCIETY, P. O. Box 2698, San Pedro, CA 90731
ANIMAL PROTECTION INSTITUTE, INC., P. O. Box 22505,
Sacramento, CA 95822
ANIMAL WELFARE INSTITUTE, P. O. Box 3650, Washington, DC 20007.
CENTER FOR ACTION ON ENDANGERED SPECIES, 175 West Main
Street, Ayer, MA 01432.
CONNECTICUT CETACEAN SOCIETY, P. O. Box 145, Wethersfield,
Connecticut 06109.
COUSTEAU SOCIETY, 777 Third Avenue, New York, NY 10017
DEFENDERS OF WILDLIFE, 1244 19th Street NW, Washington, DC 20036
ELSA CLUBS OF AMERICA, P.O. Box 4572, North Hollywood, CA 91607.
ENVIRONMENTAL DEFENSE FUND, 1525 18th Street NW,
Washington, DC 20036
FRIENDS OF THE EARTH. 124 Spear Street, San Francisco, CA 94105.
FUND FOR ANIMALS. 140 West 57th Street, New York, NY 10019
GENERAL WHALE. 9616 MacArthur Boulevard, Oakland, CA 94605.
HUMAN/DOLPHIN FOUNDATION. P.O. Box 4172, Malibu, Ca. 90265.
HUMANE SOCIETY OF THE UNITED STATES, 2100 L Street NW,
Washington, DC 20037
INTERNATIONAL SOCIETY FOR THE PROTECTION OF ANIMALS,
29 Perkins Street, Jamaica Plain, MA 02130
MENDOCINO WHALE WAR. Box 383, Mendocino, Ca 95460.
MONITOR, INC., 1522 Connecticut Avenue NW, Washington, DC 20036.
NATIONAL AUDUBON SOCIETY, 950 Third Avenue, New York, NY 10022.
NATIONAL WILDLIFE FEDERATION, 1412 16th Street NW,
Washington, DC 20036
NEW YORK ZOOLOGICAL SOCIETY, The Zoological Park,
Bronx, NY 10460
OCEAN EDUCATION PROJECT, 245 2nd Street NE, Washington, DC 20002.
OCEAN RESEARCH AND EDUCATION SOCIETY, 51 Commercial Wharf,
Boston, MA 02110.
PROJECT JONAH, Building 240, Fort Mason, San Francisco, CA 94123.
RARE ANIMAL RELIEF EFFORT (RARE), c/o National Audubon
Society, 950 Third Avenue, New York, NY 10022.
SIERRA CLUB, 530 Bush Street, San Francisco, CA 94108.
THE WHALE CENTER, 3929 Piedmont Avenue, Oakland, CA 94611.
WHALE PROTECTION FUND, Center for Environmental Education,
2101 L Street NW, Washington, DC 20037.
WORLD WILDLIFE FUND, 1601 Connecticut Ave., NW, Washington, DC
20009.

Save The Seals



MORE ONE STEP FURTHER....

Does it work? It's really our only hope and the letter below is proof that we can make our voices heard and we can have an effect. Go and do it!



DEPARTMENT OF STATE
Washington, D.C. 20520

August 28, 1979

Mr. and Mrs. James A. Kolb
P.O. Box 211
Indianola, Washington 98342

Dear Mr. and Mrs. Kolb:

Thank you for your letter to Secretary Vance expressing your strong support for the protection of whales.

The United States has actively supported whale conservation and protection through its membership in the International Whaling Commission (IWC) and played a key role in making this year's annual IWC meeting the most successful in its history. I am pleased to report on some of the progress made.

Perhaps most importantly, the IWC adopted a moratorium on factory ship whaling operations in all oceans and for all species except the relatively plentiful minke whale. This should severely curtail Japanese commercial whaling and could lead to the end of all Soviet commercial whaling. In that case, only a single factory ship operation, belonging to Japan and limited to minke whales, would remain. In addition, the IWC imposed stricter quotas for all commercial whaling, reducing overall quotas by approximately 23 per cent and by 77 per cent for sperm whales from last year's levels. Although the United States had proposed a moratorium for both deep sea and coastal whaling, we believe these IWC actions are major steps forward.

A strong precedent for future conservation and protection efforts was established when the IWC set most of the Indian Ocean aside for ten years as a whale sanctuary. This is the first whale sanctuary the IWC has created in sixteen years, and no commercial whaling will be allowed in the affected area.

The members also adopted a resolution nearly doubling the size of the IWC budget, a step that will sharply increase the support the IWC's Scientific Committee needs to improve the analyses essential for a sound program of

- 2 -

whale conservation. Along these lines, the IWC membership agreed to expand the International Observer Program to enhance monitoring of all whaling operations. The present agreement allows observers from non-whaling nations to monitor the whaling operations of IWC members. The IWC recommended that existing observer agreements with Japan be expanded to include minke whaling and that all whaling by the Republic of Korea be subject to observation. The IWC also suggested that the United States, Canada, and Denmark negotiate an agreement to provide Eskimo observers for all of their aboriginal whaling operations.

The depth and earnestness of American public opinion, the efforts of the U.S. environmental community, support from the Congress, and the President's strong personal interest all were important factors in the enormous strides made this year toward effective whale conservation. We appreciate the concern you have expressed and share your view that whales are a global asset to be held in trust for future generations. We will do all we can to make even greater progress in protecting the world's whale population.

Sincerely,

Hodding Carter III

Hodding Carter III
Assistant Secretary
for Public Affairs and
Department Spokesman

TEACHER BACKGROUND - The Scrimshander

Whales and whaling conjure up mental images of sailing ships and days gone by. As we'll see later, the days are, unfortunately not entirely gone. "The Scrimshander" serves to introduce your students to a truly American folk art form. The year long voyages provided ample opportunity to engage in hobbies. The range in artistic ability found in scrimshaw pieces runs from exquisite to primitive. On many whalers everyone from the captain to the lowest crewman would have a piece of scrimshaw in progress. The favored pieces to carve were teeth and baleen. The baleen became elaborate corset stays, while the teeth sometimes retained their shape and other times became pastry wheels or other domestic articles. The artform was so absorbing that lookouts would oftentimes not report the sighting of a whale so as not to disturb their carving. In place of whale teeth and baleen, this activity uses beef bones. The activity is enjoyable and clearly reveals the patience possessed by the seamen. The techniques first appeared in the "Massachusetts Marine Educators' Newsletter" and later in "Current, The Journal of Marine Education" (Volume 1, Number 1, Fall 1979).

Soup bones will provide the raw material for this activity. Most butchers are willing to cut the bones into 2-1/2 inch lengths for you if you explain how you are going to use them. If your butcher is very friendly, she may cut the lengths in half lengthwise so that the pieces more nearly resemble whale teeth. For advanced scrimshanders, it is sometimes possible to find old piano keys in second hand shops. Have your students practice on soup bones before they work on piano keys.

There are two ways to prepare the beef bones:

1. Boil bones for 2-1/2 to 3 hours to remove meat and gristle. (Make soup with the broth!) Scrub bones and remove all excess meat and debris. Reboil the bones for half an hour in a strong detergent solution to remove the grease. Pat bones dry and leave to dry for 3 to 4 days. You may wish to put them in the oven on racks for a few hours for drying.
2. Boil bones for 2-1/2 to 3 hours to remove meat and gristle. (Make soup with the broth!) Scrub bones and remove all excess meat and debris. Reboil the bones for half an hour in a strong detergent solution to remove the grease. Soak in

sodium hydroxide for 5 days to 2 weeks to remove excess meat, gristle and marrow. Pat dry and leave to dry for a day.

Provide sufficient sandpaper for your students to smooth the bone surfaces. One four-inch square of coarse and two four-inch squares of finer grit papers are required for each student. The choice of carving tools is limited only by your imagination. The traditional tool was the ubiquitous sailor's pocket knife. The highlighting materials used by whalers ranged from soot from the fires used to render or "try" the oil from the blubber, to paint, to tar and India ink. Most often the pigments were black, but red, green and blue highlighting is also seen on some pieces. A variety of pigments may be used by your students. Lampblack may be found in some old, well stocked hardware stores. Charcoal, pastels and crayons also work well. Felt tip pens tend to penetrate the bone and as a result do not work well. Let your students be as creative in their pigment choice as the original artisans. Disasters may be sanded away with a little effort!

Duplicate the activity pages. One set is recommended per student. Caution your students about the use of sharp carving tools and circulate through the room as the activity is performed to minimize the likelihood of accident. Plan to display the finished pieces (perhaps in the library or some other central location). You may provide extra bones for interested students to take home and carve. Provide resources and the incentive to follow up on the scrimshaw with reading and projects dealing with early whaling. This activity provides an excellent opportunity for favorable "P.R." for your program and for the school. Make the most of the opportunity.

KEY WORDS

baleen

crevices

finish

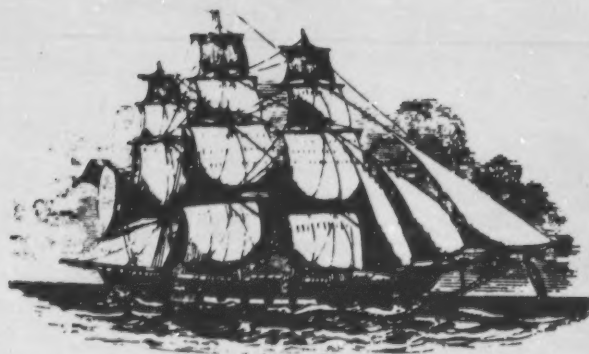
lampblack

pigment

scrimshander

scrimshaw

THE SCRIMSHANDER



"Hail! What boat are you?"

"The Mary Catherine, one hundred and ninety days out from New Bedford bound for Greenland, in search of the whale."

Seamen are condemned to spend a part of their lives in a very restricted place of work which they cannot leave for long periods at a time. For the sailing whalers on the Mary Catherine, the cruise had already lasted over half a year. It would probably be two, three or four years before the crew returned to their home port of New Bedford, Massachusetts. Sailing was hard work in bad weather and there was very little free time. In fine weather, the crew of a sailing ship had enough spare time to engage in various hobbies. Whalers passed the time of day carving sea scenes, initials, designs, their ship and the catch and other depictions of life at sea. The carving was done on the teeth of sperm whales or other toothed whales or on "whalebone," the baleen of the non-toothed whales. In the following activity you will have an opportunity to try your hand as a "scrimshander."

Materials:

Beef bones

Old piano keys

Nails, compass, single edged razor blades or any type of carving tools

Sand paper (two fine papers and one coarse paper are needed; a 4-inch square of each)

Lamp black or charcoal, pastel chalks, crayons, etc.

Procedure:

1. Sandpaper the bone. Spend a good deal of time smoothing the bone. Experiment with all grades of paper for the best finish.

2. Draw a design lightly on the bone. The first time, keep it simple. It does not have to deal with whaling.
3. Carve out design with nail or other carving tool.
4. Fill in design with lamp black or other pigment. (Caution: A little lamp black goes a very long way.) Be sure to fill in all the crevices. If the design needs more carving, do it and refill with pigment.
5. Polish the bone with a soft rag for the final gleam.
6. Display your scrimshaw work of art.

TEACHER BACKGROUND - The Blue Whale - Three Level Guide

"The Blue Whale" is an interesting account of a fascinating animal. Not the least interesting thing about the article is the fact that it was written nearly two decades ago - before the blue whale became the cause célèbre. While our knowledge of cetaceans has increased since the article was written, the information contained still gives a good overview of what we know about this largest of all creatures.

This article is difficult reading for many students. It seems to typify a problem seen in teaching today; we can have articles that cover the material but are too difficult to read, or we can have articles that can be read but do not cover the material. The three level guide presented here is one way to solve this seeming dilemma. Three level guides are based on what seems to be the general agreement that comprehension can take place at different levels of cognition. Harold L. Herber has called these levels 1) literal; 2) interpretive; and 3) applied. With the exception of the literal level, each level requires the product of the previous level or levels in order to function. The literal level of comprehension produces knowledge of what the author said. We all recognize that it is quite possible to identify and even repeat what an author has said without understanding what he meant by his statements. The interpretive level of comprehension depends upon the reading performed at the literal level but carries the process a step further. At this level the reader derives meaning from what the author has said. The meaning is determined by the way the reader perceives the intratext relationships. The applied level of comprehension takes the product of the literal (what the author has said) and the interpretive (what the author meant by what he said) and applies it in some practical or theoretical exercise. At this level the reader is using his past experiences and knowledge to produce new ideas which extend beyond those immediately identifiable in the reading selection. It must be borne in mind that the level at which a person reads does not reflect upon her intelligence and that the level can change as the material changes. The most advanced engineers and scientists often read at the literal level if they cross into other disciplines. When we read materials from an area with which we have little familiarity, our level of comprehension goes down. Your students are no exception to this

observation. The three level guide is a device used to improve a person's comprehension by focusing on important concepts at each of the three levels. The three level guide can be used with any material and is readily constructed. For aid in this regard please see:

Teaching Reading in the Content Areas, 1970, Harold L. Herber, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 296 pages.

Duplicate the pages of the three level guide, one set for each student. Spend a few minutes describing what is expected of the student. Suggest that the students read the statements in the three level guide before they read the article. In this way, the statements serve as a preview and your students will be looking for and expecting to see certain concepts. You may elect to have your students compare their answers by meeting in small groups. The process of resolving differences in opinion can be very instructive. Upon completion of the reading of the three level guide, discuss the guide by reference to the article. It is sometimes helpful to have your students note the page number and paragraph number where they found evidence supporting or refuting the statements in the guide. You can require your students to provide this information or you can offer extra credit for those that include it. Choose the technique that most appeals to you and best fits the needs and skills of your class. In this reading guide the literal level section has been modified to provide the information necessary to complete a "connect the dots" picture of a whale and calf. This variation on the standard three level guide theme shows the flexibility and potential of this proven practice.

KEY

A completed "connect the dot" and guide follows the "KEY WORDS" section.

KEY WORDS

Antarctic
baleen
blue whale
blue whale units
crustaceans
echo-location
finback
floating factories
generalization
harpoon
harvest
interpretation
krill
marine mammals
paraphrased
plankton
quota
regenerate
rorqual
taxonomist
temperate

THE BLUE WHALE - Three Level Reading Guide

Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and complete the sentences by choosing the correct word from the word list below. The statements are what the author actually said or are paraphrases of what the author said. To help you complete the sentences, the page number and paragraph number where the information occurs is given in parentheses after each statement. Notice that after each word on the list, there is a series of numbers. Use these numbers to connect the correct dots on the drawing that follows. Not every dot will be used and they are not necessarily connected in ascending numerical order. You will be able to determine if your answers are correct by the drawing that results from your connected dots.

- A. The blue whale is the largest living creature that has ever inhabited the earth. (p. 46, paragraph 1)
- B. The blue whale belongs to the rorqual, or finback, group. (p. 46, paragraph 2)
- C. Sven Foyn's invention of the explosive harpoon solved the problem of whales that sink when killed. (p. 46, par. 3)
- D. Most blue whales have been taken in the last 50 years in Antarctic waters by "floating factories." (p. 47, par. 1)
- E. Most of the blue whale's swimming power comes from the tail. (p. 47, par. 2)
- F. A blue whale feeds by scooping up crustaceans in the sea water, closing its mouth and squeezing the water out through fringed baleen plates. (p. 47, par. 3)
- G. Whales can feed underwater without getting water into their lungs, because their windpipe passes through as a separate tube. (p. 47, par. 4)
- H. A whale's sense of hearing and echo-location abilities are very good. (p. 47, ~~par.~~ 5)

- I. Whale calves grow rapidly, in part because the rich milk upon which they feed contains as much as 38 percent fat.
(p. 49, par. 3)
- J. Blue whales feed on plankton and krill. (p. 49, par. 5)
- K. Blue whales reach sexual maturity at four or five years. (p. 49, par. 7)
- L. The fact that most blue whales bear a calf only every other year is an important consideration in the effort to protect and regenerate the stocks of blue whales. (p. 49, par. 8)
- M. Whale treaty agreements have harvest figures based on blue whale units. (p. 50, par. 1)
- N. Because the blue whale has been over harvested, whalers have turned their attention to the fin whale. (p. 50, par. 2)

WORD LIST

Antarctic (28,38,40,46,49,54)

Arctic (23,25,26,28,29,38)

baleen (68,71,74,82,85,87)

blue (4,1,3,6,7,9)

blue whale units (300,311,321,341,
349,412)

Eustachian tube (87,96,101,102,115)

fat (147,156,165,169,171)

fin (412,558,641,799,847)

finback (5,9,10,11,14,18)

five (203,217,219,220,230,247)

foreflippers (321,349,412,799,847)

four (197,199,200,202,203)

krill (171,183,188,194,196,197)

harpoon (18,21,23,26,28)

hearing (114,121,125,139,140,147)

Pacific (14,15,16,17,18)

regenerate (247,251,269,281,300)

sei (1,2,4,5,7)

sperm (4,5,8,10,11,12)

steam boat (102,103,121,140,147)

tail (54,60,63,67,68)

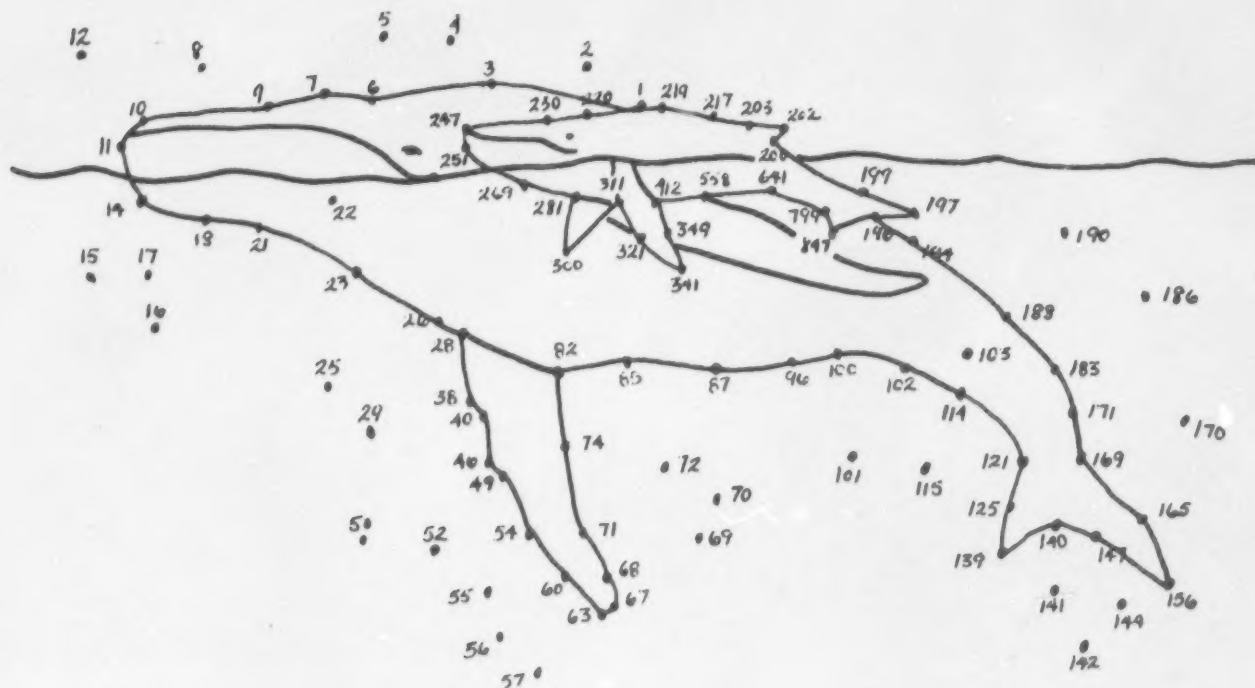
teeth (49,54,71,74,82)

three (321,349,412,558,847)

two (200,202,247,311,321)

windpipe (87,96,100,102,114)

Directions: Use the number sequences from the completed Level I sentences to connect the correct dots.



Level II. Directions: The statements below may or may not be true. Check each statement you believe is a generalization the author himself draws, based on the information he gives in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference.

- _____ Taxonomists who classify marine mammals have agreed that the blue whale should be called *Sibbaldus balaenoptera*.
- _____ Sophisticated ships and equipment have enabled modern whaling to be less destructive to whale populations than earlier whaling techniques.
- X The great expense of floating factories increases the incentive to kill larger numbers of whales to pay off the investment.
- X Whales have evolved sophisticated structures and behaviors to survive in the oceans.
- X The fact that whales disperse into the immense temperate oceans to mate and calve worries scientists who fear that if the population size is small, the mates won't be able to locate each other.
- X A decrease in the size of captured whales is an indication of over fishing.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to the next level.

Level III. Directions: Read each statement below, relating the details and author's interpretations drawn from the selection to ideas and experiences you've had in reference to this topic. In column A, check the statements which Ruud would have agreed with. In column B, check the statements you agree with.

A	B	
<u>X</u>	_____	Since blue whale populations have continued to decrease in spite of whale quotas, stronger protective measures are needed.
_____	_____	From their experience with blue whales, whalers have learned the value of conservation and lower harvest limits.
<u>X</u>	_____	Harvesting large numbers of whales under four or five years old will have a serious impact on the existence of whales.
<u>X</u>	_____	There's a sound in the sea that's growing quieter..... quieter.....quieter.

Directions: Again, compare your answers with your group. Where there are differences, try to resolve them.

THE BLUE WHALE

Although its commercial importance has dwindled, it is the largest animal that ever lived. Some specimens are 100 feet long and weigh 150 tons. A blue whale calf grows at a rate of 200 pounds per day!

by Johan T. Ruud

(Sulphur Bottom).—Another retiring gentleman, with a brimstone belly, doubtless got by scraping along the Tartarian tiles in some of his profounder divings. He is seldom seen; at least I have never seen him except in the remotest southern seas, and then always at too great a distance to study his countenance. He is never chased; he would run away with rope-walks of line. Prodigies are told of him. Adieu, Sulphur Bottom! I can say nothing more that is true of ye, nor can the oldest Nantucketer.

This quotation from Herman Melville's chapter on "Cetology" in *Moby Dick* illustrates how little was known 105 years ago about the king of whales. Melville elected the sperm whale as the leviathan of the seas, but the sperm was almost a runt compared to the sulfur-bottom, now better known as the blue whale. The blue whale is by far the biggest living creature that has ever inhabited the earth. At its fullest growth it is about three times more massive than were the extinct dinosaurs. Since Melville's day it has been chased as no whale ever was chased before, and for decades hunters of the sea have prized the blue whale as the mightiest game on our planet.

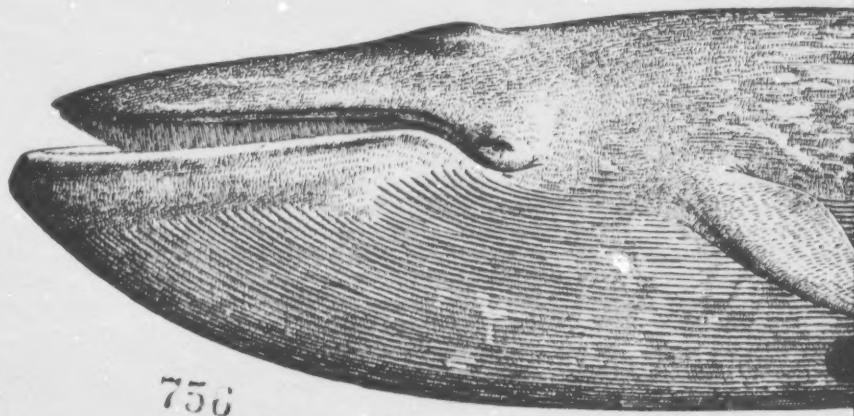
The species gets the yellowish color of its underside from a thin film of diatoms living on its bottom surface, but its back has a bluish color, which accounts for its present more common name. The blue whale belongs to the rorqual, or finback, group. It was first reported by Robert Sibbald, a Scottish scientist, who examined a specimen stranded in the Firth of Forth in 1692. Carl von Linné (Linnaeus) later named the species *Balaena musculus*. Either the

was not sufficiently specific or later naturalists were led astray by an irresistible urge to discover new species, because in the following 150 years we find the blue whale acquiring a score of different Latin names. At the turn of the 20th century Frederick W. True of the U. S. National Museum brought order out of the confusion of Latin names. There is still a slight difference, however, between the European and American classifications: in Europe the blue whale is considered to be of the same genus as all the other finbacked whales and is called *Balaenoptera musculus*, while in the U. S. it is placed in another genus and called *Sibbaldus musculus*.

As Melville said, American open-boat whalers of his day never chased the blue whale: they considered it too fast and violent, and inferior in value to either

the right or the sperm whale. However, toward the end of the mid-18th century whaling era, when right and sperm whales had become scarce, attempts were made to kill the blue whale from open boats with explosives shot from swivel guns. This proved fruitless, because blue whales, in contrast to right whales, usually sink when killed. The difficulty was mastered when Captain Svend Foyn of Norway, the founder of modern whaling, introduced the steam-powered catcher. This is a small steamer furnished with a cannon that fires a grenade-headed harpoon. With this efficient weapon Foyn was able to kill the giant whale and tow it to a shore base, where it could be stripped of blubber, dismembered and cooked.

In the course of 90 years of modern whaling, a total of about 350,000 blue



BLUE WHALE is depicted as it would appear if its vast bulk could be viewed as it floated in the water. Its back has a bluish color; its underside is yellowish and pleated. When the

whales have been killed in all waters of the world. Most of these (91.4 per cent) have been taken in the last 50 years in Antarctic waters, a large proportion of them by "floating factories" operating on a mass-production basis. From these immense catches cetologists have obtained a wealth of anatomical and statistical information about the blue whale.

No photograph can do full justice to this huge animal. It cannot be properly photographed in the water; only a good draftsman can give a true impression of the blue whale's beautifully modeled body [see drawing on these two pages]. The skin is hairless and extremely smooth, the shape of the body completely streamlined. The foreflippers, which are stiff and comparatively short and narrow, act as rudders for steering and balancing. Propulsion is provided by the whale's powerful tail, whose broad, horizontal flukes, stroking up and down in the water, easily give the blue whale a sustained speed of five to 10 knots; in short spurts it can travel faster than that. Modern whaleboats of 16 or 18 knots often need considerable time to overtake it.

Blue whales are baleen whales, i.e., they have no teeth in their jaws, but thin plates of whalebone (baleens) are attached to the upper palate. The baleens, fringed at the edges, form a grid or sieve with which the whale traps its food—tiny shrimplike crustaceans called "krill." It was the whalebone, used for a variety of purposes where to-

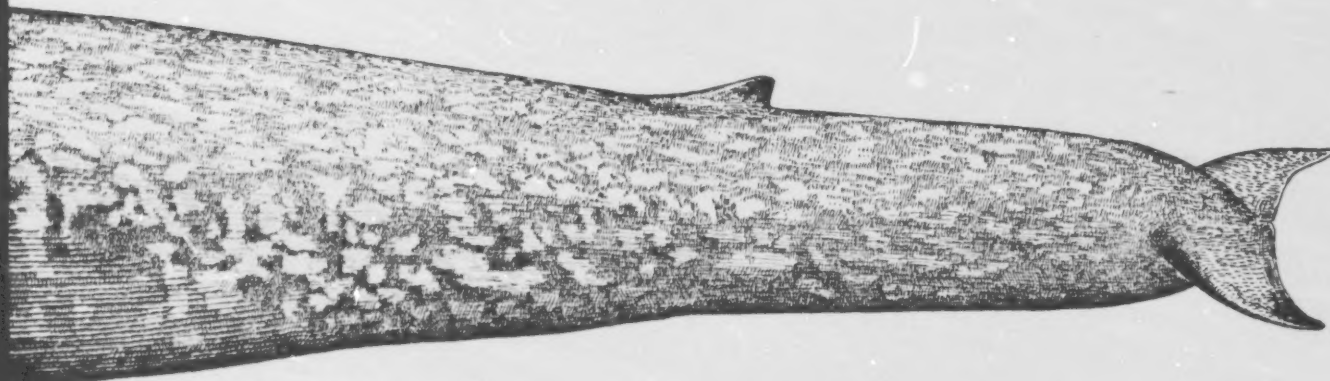
day we use plastics or steel, that made the right whale so highly prized; the blue whale was considered less valuable because its baleens are not as flexible and are considerably shorter—three feet instead of 12 feet. The blue whale's collection of food is assisted by the peculiar construction of its brimstone belly, which is wrinkled, or pleated, from the chin to the navel [see photograph on next page]. This gives its underside a flexibility which allows its mouth to hang down as a huge bag for scooping up crustaceans in the sea water; when the whale brings its jaws together, closing the bag, contractions of its pleated belly squeeze the water out between the fringed baleen plates, while the bag retains the food.

The whale is a lung-breathing mammal and must rise to the surface to take in air at more or less regular intervals. Through its blowholes, nostrils conveniently located on the top of its head, it forcefully expels air from its lungs and immediately takes a deep breath. The warm, moist expired air condenses as soon as it is discharged into the colder atmosphere, and the whale's expiration is visible for miles as a high, springing fountain. A blue whale traveling at ease will rise to the surface for a minute or two, blow three or four times and sound again for 10 to 15 minutes. It can feed under water without getting water into its lungs, because its windpipe passes through its throat as a separate tube.

Most of the blue whale's senses are rather weakly developed according to human standards. Its eyes cannot see

very far, but this does not matter much, because of the short range of visibility under water. The whale's anatomy indicates that its sense of smell must be inferior. Whalers agree, however, that its sense of hearing is very good—some think too good. At the Marineland Studios in Florida, where porpoises are held in captivity in big ponds, investigators have discovered that these small, toothed whales are capable of echolocating their prey. They emit squeaking signals and evidently can pick up echoes from other animals in the water and decide their direction. This is reminiscent of the supersonic echo-location used by bats, and a Dutch anatomist has demonstrated a correspondence between anatomical structures in the ears of bats and of whales. Quite recently specialists in underwater noise at the Woods Hole Oceanographic Institution have recorded sounds emitted by right whales swimming nearby. So it seems possible that baleen whales locate their tiny prey by tracking the echoes of sounds they themselves emit.

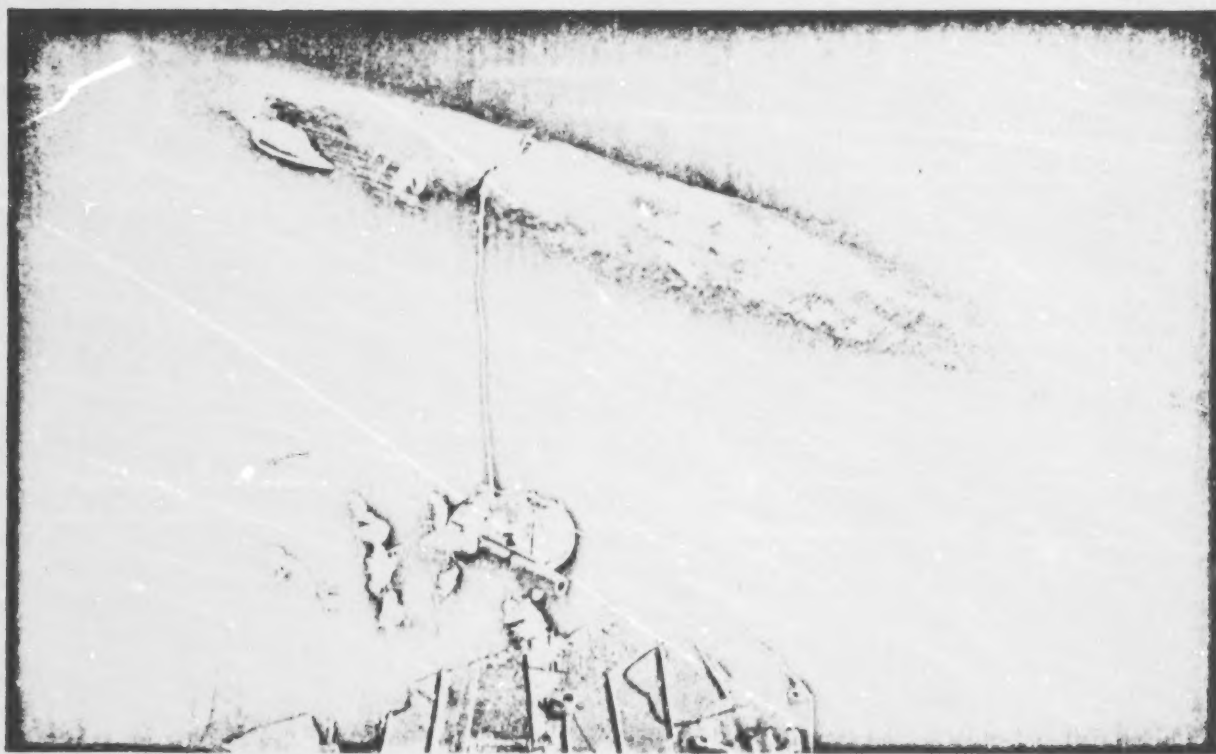
The biggest blue whales reported have been 100 feet long or more and weighed 150 tons. (For comparison, the giant extinct dinosaurs are estimated to have weighed 40 to 50 tons, and the largest present land mammal, the elephant, weighs three to four tons.) The average blue whale taken in the Antarctic today is 78 or 79 feet long and weighs 80 to 85 tons. This means that in the last 50 years 25 million tons of blue whales have been taken in Antarc-



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whale feeds, it drops its lower jaw like a huge bag to collect small crustaceans. The lower jaw is then closed and its content of water

is forced out through the fringed baleen plates suspended from the upper jaw. This process filters the crustaceans out of the water.



DEAD BLUE WHALE is hauled in by a Japanese catcher vessel. The whale is lying on its side; its tail is at the right. Part of its

pleated bottom may be seen to the right of the flipper at the left. The harpoon, still attached to its line, is in the whale's back.



HEAD OF THE SAME WHALE is photographed from the catcher. In the nose-like structure at upper right are its blowholes. A blue

whale swimming without effort will sound for 10 to 15 minutes, surface, blow three or four times in a minute or two and sound again.

tic waters—a weight equal to the total annual catch of the world's fisheries.

Weighing a blue whale requires several hours' hard work, because the huge beast has to be weighed piecemeal. Until recent years only three weighings of blue whales had been reported. But since 1947 Japanese scientists have weighed more than 30 in the Antarctic, and accurate figures are therefore now available [see chart below]. Of the total weight of the average blue whale, blubber accounts for 27 per cent, meat for 30 per cent, bone for 18 per cent and internal organs for 12 per cent. The heart alone may weigh as much as 1,300 pounds, and the kidneys, 1,078 pounds.

A newborn blue whale calf is about 23 feet long and weighs two and a half to three tons. At weaning, which is assumed to take place seven months after birth, the calf weighs about 23 tons. Whale milk is extremely nourishing, containing as much as 38 per cent fat, which probably explains why the calf grows at the amazing rate of about 200 pounds per day. However, compared to the explosive growth of a baby elephant seal or harp seal, the daily gain of the blue whale suckling is moderate—3 to 4 per cent of the birth weight.

At the age of 19 months a young blue whale is about 66 feet long and weighs 45 to 50 tons. At puberty (about four years) its weight has reached some 70 or 75 tons. It has gained an average of about 88 pounds a day on its own, which is remarkable when we consider that its diet consists of tiny crustaceans.

Blue whales are most abundant in the biologically productive areas of the oceans where plankton and krill abound. In summer they migrate to the high Arctic and Antarctic latitudes as swarms of plankton grow in the wake of the retreating ice; blue whales are supposed to penetrate farther into the icy regions than any other species. In the autumn they go back to temperate waters, where mating and birth take place. The newborn calf has only a thin insulation of blubber and would probably freeze to death if born in the icy waters of Arctic or Antarctic areas.

We know neither the migration routes of the blue whales nor their nursing grounds. In summer they are concentrated in rather narrow belts in the polar seas, but it is believed they disperse over wider fields when they leave these feeding grounds, because nowhere in lower latitudes have whalers encountered blue whales in numbers comparable to those seen in high latitudes. Blue whales are not gregarious; they

are seldom seen in groups of more than two or three.

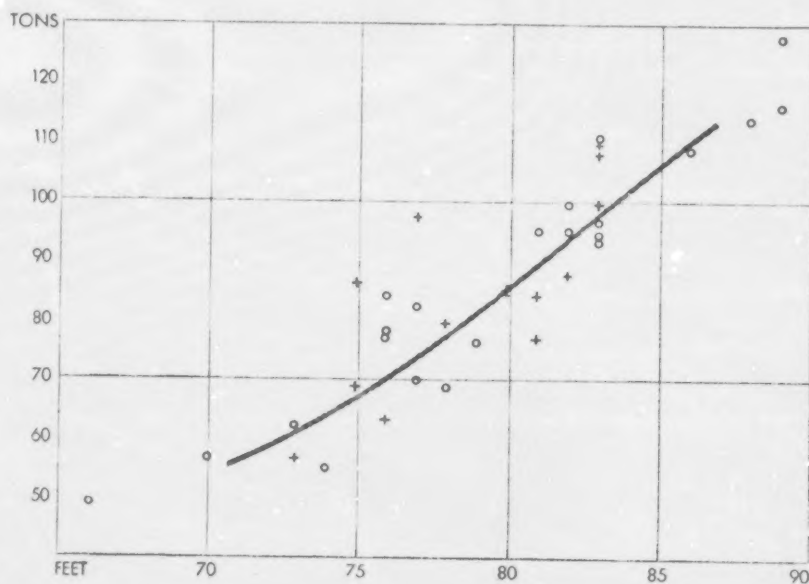
Our knowledge of the life history of the blue whale has gradually been pieced together by studies conducted at whaling stations in all waters, from the Arctic shores of northern Norway to the island of South Georgia in the Antarctic, from stations in the Far East to stations in British Columbia. By examination of pregnant females, which are unavoidably killed in considerable numbers every season, we can trace the growth history of the fetus. These studies show that pregnancy lasts 10 or 11 months. Mating takes place mostly in winter. In the southern seas most of the calves are born in April. Because the growth of blue whales after weaning varies greatly, it is not easy to judge their age. The ages of sexually mature females can be estimated from the number of *corpora albicantia* (scars left by burst follicles) in their ovaries. In 1940 Norwegian and Russian scientists independently found a more general index of age—annual growth zones in the baleen plates. However, there is a snag to this method, for the whales continually wear down the baleen plates from the edge. Nevertheless Japanese and Norwegian workers have learned by this index that blue whales usually attain sexual maturity at four or five years, rather than at two years as was formerly supposed. A more promising method of

age determination has been developed recently by English scientists. The ear tube of baleen whales is completely filled by a waxlike plug, which may have something to do with conducting sound from the outer opening to the inner ear. The important point is that the plug grows with the skull and shows very distinct growth zones. This was discovered only a year ago, and the first extensive collection of plugs was made during the Antarctic season 1955-56.

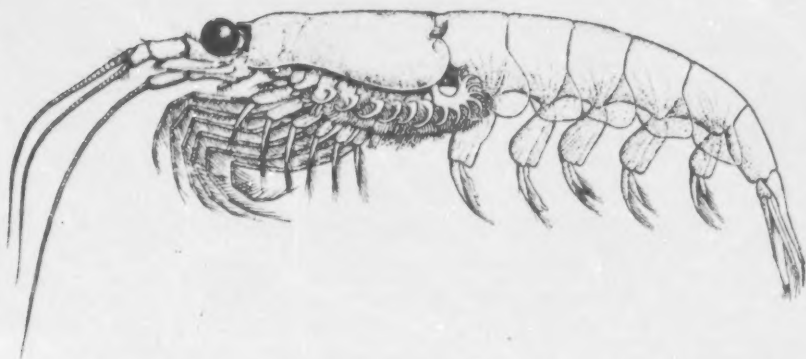
A blue whale seldom bears more than one calf at a birth. From the fact that about half of the sexually mature females taken by whalers in a season are pregnant, we can assume that most blue whale females bear a calf every other year. This is an important consideration in the effort to protect and regenerate the stocks of blue whales.

Blue whales are eagerly sought as the most valuable prey by modern whalers. Although they made up only 15 per cent of the whales sighted in the Antarctic in the seasons before the last war, they are so prized that they accounted for most of the catch. In the peak season of 1930-31 a fleet of 41 floating factories killed 28,325 blue whales, 8,601 fin whales and 510 humpbacks.

There is ample evidence that blue whales were greatly overfished in the 1930s. Fewer large whales were found as time went on, and the catches consisted more and more of small and immature ones. As blue whales became less



WEIGHT OF 36 ANTARCTIC BLUE WHALES is plotted against their length. The crosses indicate males; the circles, females. The whales were weighed piecemeal by investigators.



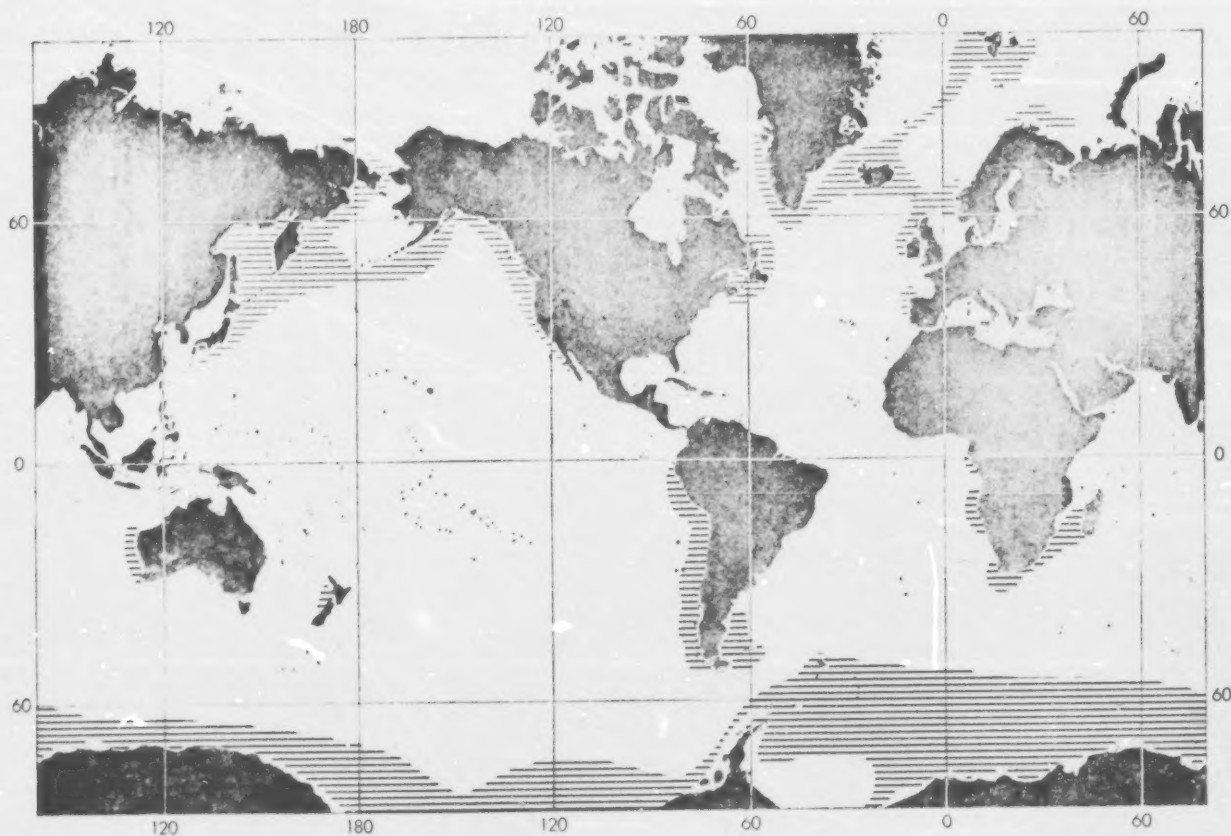
BLUE WHALE FEEDS on small shrimplike crustaceans which are called "krill." This drawing depicts a southern species of krill, *Euphausia superba*, enlarged about two times.

abundant, the whalers paid more attention to the second-best whale, the fin-back. The relative number of blue whales in Antarctic catches went down from about 76 per cent in 1930-31 to about 35 per cent in the last season before the war. After the war a degree of protection was given to blue whales by an international convention for the regulation of whaling, signed at Washington, D.C., in 1946. An over-all ceiling

on the number of whales that could be taken per season by the Antarctic floating factories was established. The total catch was restricted to 16,000 units (later further reduced to 14,500 units). The unit is one blue whale. A blue whale gives about 20 tons of oil, a fin whale 10 tons and a humpback whale 8 tons. Thus one blue whale unit amounts to one blue whale or two fin whales or two and a half humpback whales. To

encourage the taking of fin whales rather than blue whales, a later opening date has been set for the whaling season and a still later one for blue whales (which migrate to the Antarctic earlier than fin whales). Nevertheless the stock of blue whales has continued to decline.

History repeats itself, and whaling is no exception. Bowheads and right whales were depleted almost to extinction by the old open-boat whalers. Blue whales of the North Atlantic and Arctic have now been depleted so far that all the countries involved, except Iceland and the Faroe Islands, have agreed to protect them completely for a period of five years. In the Antarctic also the blue whale is following the right whale. Between 1914 and 1928 annual catches of 2,000 to 3,000 blue whales by whalers based at South Georgia were not unusual; last year only three blue whales were taken by 21 modern catchers in a six-months' season. Today the whaling economy depends on the catches of fin whales. The blue whale has become industrially unimportant. But its surviving members remain the greatest creatures that have ever lived on the earth.



GEOGRAPHICAL DISTRIBUTION of the blue whale is outlined in color on this map. The colored areas are waters where blue

whales have been caught in the operations of modern whaling. In some of them they are greatly depleted and even near extinction.

THE BLUE WHALE - Three Level Reading Guide



Level I. Directions: Read the statements carefully. Then as you read the selection, refer back to the statements in the guide and complete the sentences by choosing the correct word from the word list below. The statements are what the author actually said or are paraphrases of what the author said. To help you complete the sentences, the page number and paragraph number where the information occurs is given in parentheses after each statement. Notice that after each word on the list, there is a series of numbers. Use these numbers to connect the correct dots on the drawing that follows. Not every dot will be used and they are not necessarily connected in ascending numerical order. You will not be able to determine if your answers are correct by the drawing that results from your connected dots.

- A. The _____ whale is the largest living creature that has ever inhabited the earth. (p. 46, paragraph 1)
- B. The blue whale belongs to the rorqual, or _____, group. (p. 46, paragraph 2)
- C. Sven Foy's invention of the explosive _____ solved the problem of whales that sink when killed. (p. 46, paragraph 3)
- D. Most blue whales have been taken in the last 50 years in _____ waters by "floating factories." (p. 47, paragraph 1)
- E. Most of the blue whale's swimming power comes from the _____. (p. 47, par. 2)
- F. A blue whale feeds by scooping up crustaceans in the sea water, closing its mouth and squeezing the water out through fringed _____ plates. (p. 47, par. 3)

- G. Whales can feed underwater without getting water into their lungs, because their _____ passes through as a separate tube. (p. 47, par. 4)
- H. A whale's sense of _____ and echo-location abilities are very good. (p. 47, par. 5)
- I. Whale calves grow rapidly, in part because the rich milk upon which they feed contains as much as 38 percent _____. (p. 49, par. 3)
- J. Blue whales feed on plankton and _____. (p. 49, par. 5)
- K. Blue whales reach sexual maturity at _____ or _____ years. (p. 49, par. 7)
- L. The fact that most blue whales bear a calf only every other year is an important consideration in the effort to protect and _____ the stocks of blue whales. (p. 49, par. 8)
- M. Whale treaty agreements have harvest figures based on _____. (p. 50, par. 1)
- N. Because the blue whale has been over harvested, whalers have turned their attention to the _____ whale. (p. 50, par. 2)

WORD LIST

Antarctic (28,38,40,46,49,54)	hearing (114,121,125,139,140,147)
Arctic (23,25,26,28,29,38)	Pacific (14,15,16,17,18)
baleen (68,71,74,82,85,87)	regenerate (247,251,269,281,300)
blue (4,1,3,6,7,9)	sei (1,2,4,5,7)
blue whale units (300,311,321, 341,349,412)	sperm (4,5,8,10,11,12)
Eustachian tube (87,96,101, 102,115)	steam boat (102,103,121,140,147)
fat (147,156,165,169,171)	tail (54,60,63,67,68)
fin (412,558,641,799,847)	teeth (49,54,71,74,82)
finback (5,9,10,11,14,18)	three (321,349,412,558,847)
five (203,217,219,220,230,247)	two (200,202,247,311,321)
foreflippers (321,349,412,799, 847)	windpipe (87,96,100,102,114)
four (197,199,200,202,203)	
krill (171,183,188,194,196,197)	
harpoon (18,21,23,26,28)	

Directions: Use the number sequences from the completed Level I sentences to connect the correct dots.



Level II. Directions: The statements below may or may not be true. Check each statement you believe is a generalization the author himself draws based on the information he gives in the selection. Indicate the page, paragraph and sentence on the statements checked for later reference.

- _____ Taxonomists who classify marine mammals have agreed that the blue whale should be called *Sibbaldus balaenoptera*.
- _____ Sophisticated ships and equipment have enabled modern whaling to be less destructive to whale populations than earlier whaling techniques.
- _____ The great expense of floating factories increases the incentive to kill larger numbers of whales to pay off the investment.
- _____ Whales have evolved sophisticated structures and behaviors to survive in the oceans.
- _____ The fact that whales disperse into the immense temperate oceans to mate and calve worries scientists who fear that if the population size is small, the mates won't be able to locate each other.
- _____ A decrease in the size of captured whales is an indication of over fishing.

Directions: Now compare your answers with your group. As before, where there are differences, try to resolve them by reference to the selection. When you finish your discussion, go on to the next level.

Level III. Directions: Read each statement below, relating the details and author's interpretations drawn from the selection to ideas and experiences you've had in reference to this topic. In column A, check the statements which Ruud would have agreed with. In column B, check the statements you agree with.

A	B	
_____	_____	Since blue whale populations have continued to decrease in spite of whale quotas, stronger protective measures are needed.
_____	_____	From their experience with blue whales, whalers have learned the value of conservation and lower harvest limits.
_____	_____	Harvesting large numbers of whales under four or five years old will have a serious impact on the existence of whales.
_____	_____	There's a sound in the sea that's growing quieter....quieter.....quieter.

Directions: Again, compare your answers with your group. Where there are differences, try to resolve them.

TEACHER BACKGROUND - Man Destroys Them - Reading Guide

"Man Destroys Them" is an abbreviated history of whaling excerpted from the "Vancouver Public Aquarium Newsletter" (Volume XIX, Number 4, July-August, 1975). The guide provides questions next to the paragraph in which the answer occurs. This format helps your students to recognize and grasp the important ideas in material that might otherwise be difficult reading. The article provides only the outline of an incredibly fascinating story of man's interaction with the whale. To expand this outline, consult any of the references found following the "KEY WORD" section below.

KEY

1. Cetaceans are a group of animals which contain the whales, dolphins and porpoises. The context clues provided in the text will enable your students to say that cetaceans are whales.
2. This question requires some imagination. The Right Whale is the "right" whale because it floats when dead and the early whalers were able to tow them ashore. This theory provides the popular etymology of the name. Other possible sources may be divined by your students.
3. The result of Basque whaling, like the result of most whaling to date, was the virtual disappearance of the hunted whale from local waters.
4. The invention of the special trying oven was a breakthrough for whalers because they could operate without going ashore to render the whale blubber. This greatly increased the range of the whalers and expanded the waters in which they could hunt.
5. Whalers reacted to the killing off of different types of whales by turning to another type. It is well to remember, however, that there was concern voiced by whalers about overharvest even during the height of whaling in the 18th century. Unfortunately, these individuals found few receptive ears for their concerns.
6. On the average, American whalers killed 13,571 Southern Right Whales per year during the late 18th Century.

7. The whalers began to hunt the small Gray Whale because of the shortage of whales due to overhunting.
8. The change in energy source for light caused a decreased demand for whale oil, which reduced the number of whalers. Your students will have to make the step from decreased need for oil to reduction in the number of whalers based on their experience with economics.
9. The steam engine and the exploding harpoon allowed whalers to pursue species that had been too large and too fast for sail whaling with hand harpoons. A third innovation, involving pumping compressed air into the whale, enabled the whaling of species that commonly sink after death. The threat to the whale's existence came from the fact that now no whales were immune to the hunt.
10. Factory ships have "spelled doom for the whales in the 20th Century" because the building and equipping of expensive pelagic fleets of whalers necessitated relentless killing to pay off the investments.
11. This is a trick question. Obviously, any moratorium will be too late to help any species already hunted to extinction. This question is designed to provide material for a discussion of the finality of extinction and the risk to the human species from the extinction of other animals. Emphasize the interrelationships that exist among all living organisms.
12. The effect of whaling in all of the areas mentioned has been to hunt the whale to the brink of extinction. Use this question to discuss the "pioneer mentality" of the whalers. The whale could be decimated in one area because there were always more in other areas. We've obviously come to the point where there are no "other areas." It's time to stop mining the whale and to start managing (or let nature again manage) the whale.

KEY WORDS

average
Basque
blubber
cetacean
conservation

exploited
extinction
factory ship
harpoon
slaughter
stocks
moratorium
pelagic
petroleum
pods
whale
whaling

RESOURCES: The following bibliography from the Children's Whale Workshop Society includes materials on whales as well as on whaling.

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- Desert Whales. 22 min., color. Doubleday Multimedia, Box 11607, 1371 Reynolds Ave., Santa Ana, CA. 92705. 1970. Final part of California Grey Whale's southern migration and J. Cousteau's attempt to help a stranded whale.
- In Search of the Bowhead. 50 min. color. National Film Board of Canada. 1974. Small expedition looking for Arctic Bowhead whales. Much information. Available through Canadian Consulates or National Film Board of Canada.
 - Last Days of the Dolphins. 27 min., color. Free loan to schools and organizations. Write "Regional Film Center" nearest you. 915 NW Nineteenth Ave., Portland, OR 97209. Shows tragic killing of thousands of dolphins by tuna fishing industry.
 - The Sea. 28 min. color. National Film Board of Canada. 1971. Man's relationship to the sea: exploration and overharvesting. Excellent footage.
 - Portrait of a Whale. 12 min. color. National Geographic, 1977. Close-up photography and underwater views of southern right whales.
 - There's a Sound in the Sea. 11 min. color. Defenders of Wildlife, 1977. Grades 1-4. Colorful and entertaining film of 7 species of whales and the question of whaling.

Additional information may be obtained from the Children's Whale Workshop Society by writing them at P.O. Box 46529, Station G, Vancouver, British Columbia, Canada V6R 4G8.



MAN DESTROYS THEM - Reading Guide

1. What are cetaceans?
2. From this sentence, what is one possible source of the name "Right" Whale?
3. What was the result of Basque whaling?
4. Why was the invention of the special "trying" oven a breakthrough for whalers?
5. How did whalers react to the killing off of different types of whales?
6. On the average, American whalers killed _____ Southern Right Whales per year during the late 18th century.

The large cetaceans produce enormous quantities of meat, oil and other useful items, and there is no doubt that whaling goes far back into human history. The earliest probably involved driving ashore pods of the smaller kinds of cetaceans, as is done today in the Faroe Islands with pilot whales.

Eventually people began to hunt the large species. Prior to the 12th century, the Basques of the French and Spanish coasts used small boats, harpoons and lances to kill right whales, which were relatively easy to hunt. These animals were slow and timid and seasonally common in the Bay of Biscay. Right whales float when dead, and whalers towed them ashore where they were cut up. However, the Basques hunted so relentlessly that eventually these whales almost disappeared from local waters.

Then the whalers turned to distant shores. By the 16th century, the Basques and other Europeans were building larger boats and making voyages as far away as Greenland and Newfoundland to catch right whales. In time, they were able to remove the desired parts from a large whale while it was tied alongside a ship, and the development of a special oven enabled them to convert blubber to oil on the ship. Thus, they could operate without going ashore.

In the 17th century, the right whales disappeared from Greenland waters, and the European whalers then turned to the populations off Spitzbergen (northern Scandinavia), quickly decimating them also.

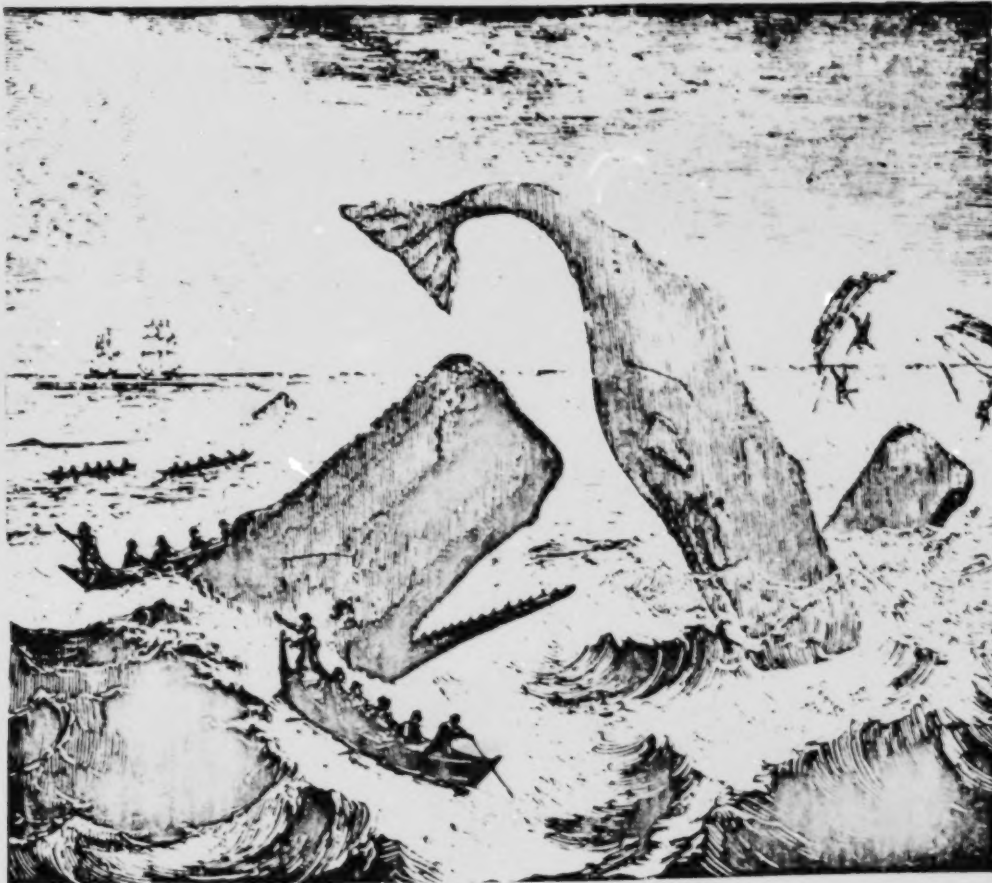
As whaling proceeded on a large scale, many species were exploited — cruelly slaughtered in the name of profit. As one type was killed off whalers turned to others. In 1680, Holland alone had 260 whaling ships, with a total crew of 14,000, and by the 18th century it had 400 whaling ships manned by 20,000 men. The 17th century Japanese used boats and nets to catch the whales that passed along their shores.

In 1774 Captain Cook opened up the Antarctic where huge concentrations of right, blue, sei and finback whales fed on the unusually large amounts of krill there.

Also in the late 18th century, the American whaling fleet was established. These whalers slaughtered all of the right whales occurring along the American coast. Then they turned to the larger, stronger sperm whales, and later the southern right whales in the Antarctic. In one 14-year period, 190,000 of the latter were killed.

7. Why did whalers begin to hunt the small Gray Whale?
8. How did the change in energy source for light affect whaling?

By the 1840's there were 824 whaling ships operating in the Pacific area alone, employing 70,000 men. In one year they caught about 10,000 sperm whales, and in the 1850's they even turned to the small gray whales. By the end of the 19th century the whaling industry was declining due to the shortage of whales. Also, whale oil for lighting was replaced by petroleum, then gas and electricity.



9. How did the two inventions mentioned further threaten the existence of the whale?

However, the respite was short for the whales, whose destiny it was to be turned into fertilizer, soap, beauty creams, vitamins, margarine and pet food during the 20th century. Two unrelated happenings enabled men to hunt whales with greater efficiency: (1) James Watt's invention of the steam engine, which led to powered boats, and (2) the invention, in 1868, by a Norwegian named Svend Foyn, of a harpoon with an explosive head that could be fired from a cannon. Whalers could hunt not only right whales, humpbacks and sperm whales, but also the gigantic blue whales and finbacks. They could now go after the larger, tastier cetaceans.



10. How have the factory ships "spelled doom for the whales in the 20th century"?

As the shore stations in the Antarctic killed off the great schools of whales, a method of chasing whales further afield had to be invented. Thus, open-ocean whaling came into existence. Large factory ships, fitted with a ramp at the stern for hauling aboard whales and boilers for rendering oil, could now follow the smaller boats wherever they went to catch whales.

It is the efficiency of these factory ships and their huge cost that have spelled doom for the whales in the 20th century. The building and equipping of expensive pelagic fleets necessitated relentless killing to pay off the investments. Thus, the remaining stocks of whales have fallen to very low levels.

11. How will a moratorium (a forced stop for a set period of time) affect those whales hunted to extinction?

Only Russia and Japan still operate very large whaling fleets, while Norway, Spain, Portugal and some South American countries operate small fleets. The International Whaling Commission (to which the smaller countries do not belong) is taking increased responsibility for whale conservation, establishing quotas with regard to whale hunting. At the present time, California gray, blue, humpback, Greenland right and Black right whales are totally protected, and some conservationists are asking for a moratorium on all whaling.

12. What has been the effect of whaling in the Bay of Biscay, the Atlantic, the Antarctic, the Arctic and the Pacific?

TEACHER BACKGROUND - The Last of the Great Whales And One Step Further....

The reading activity "The Last of the Great Whales" incorporates several reading improvement techniques as it provides your students with help in comprehending a semi-technical article from the Scientific American. The article presents background material and data necessary for an understanding of the issues involved in the current heated controversy over whaling. While the article is difficult reading for many secondary students, the materials contained merit the extra effort required by you to assure that your students successfully master the article. Since the kill data is not current, "One Step Further...." updates the information and expands on some of the concepts dealt with in "The Last of the Great Whales". Use "The Last of the Great Whales" to provide a firm, factual foundation for later discussions involving whaling, in particular, and man's interactions with marine mammals and the sea, in general.

"The Last of the Great Whales" reading activity is in four parts. Part I is a preview designed to give your students a broad overview of the article. Few students take time for or appreciate the value of a quick preview of reading materials. The preview builds certain expectations into the reader and prepares her to anticipate what is to follow. Part II contains direct or paraphrased statements from the body of the text. Part III encourages your students to use and understand the graphic aids provided by the authors. Part IV serves as a review by having your students rescan the text to excerpt samples of IWC/whaling nation disagreements.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students although there is considerable merit in having your students meet in small groups after each student has completed the guide individually. Use the approach that best suits the needs and

abilities of your class. Help your students to be successful in this endeavor. Upon completion of the guide, plan to allow a sufficient period of time to discuss the answers and the tangential topics which are sure to arise.

Additional information regarding the whaling controversy may be found in the references cited in "Man Destroys Them - Reading Guide". The opportunities for additional activities are legion: students can research and design a poster about a specific species of whale (eg. "save the narwhale" or "invite a minke whale to dinner tonight!"); write letters to politicians, and conservationists, study the history of whaling; study whale biology, etc. Expand the materials as time and interest allows.

KEY

The answers are entered on the completed guides found after the "Key Words" section.

KEY WORDS

blue whale
blue whale units
catch records
commercial
extinction
figure
great whales
harvest
International Whaling Commission
paraphrased
percentage
population
proportion
scanning
species
whaling

Part I - Preview

Directions: Before you read the article, preview "The Last of the Great Whales" by scanning the article to find the answers to the following questions.

1. What is the title and who is the author of this article?

"The Last of the Great Whales" by Scott McVay

2. How many figures are there in this article? How many of these are graphs?

9 figures - 5 graphs

3. What do you think this article is going to deal with?

Extinction of whales ... etc.

Part II

Directions: Read the following statements carefully. Check those statements that are actually stated or paraphrased in the story. Be ready to explain what is inaccurate about the statements that you do not check. After the statement, write the page number and paragraph number which gives you support for your choices.

- X 1. The purpose of the article is to trace the circumstances that led to the near extinction of about 12 species of whale. pp. 313 paragraph 1
2. Right whales gained their name because, when hunted, they can always be expected to sound (dive) to the right rather than to the left.
- X 3. Statistics related to whale capture are measured in 'Blue Whale Units'. pp. 314 paragraph 1 (or 0)
- X 4. Decreasing numbers of whales in Anarctic waters have caused the whaling fleets to spend more time in the North Pacific and other whaling regions. pp. 316 paragraph 2 (or 1)
5. The International Whaling Commission which oversees the conservation and sensible utilization of the world's whale resources has both inspection and enforcement powers. pp. 316 paragraph 4 (or 3)
- X 6. Declining catches of blue whales resulted in the more vigorous pursuit of finbacks. pp. 317 paragraph 1

7. For the 1963-64 season, the Commission forecast that if unrestricted whaling were permitted, the industry would not be able to harvest more than 8,500 blue whale units and would slaughter 14,000 finbacks in the process. The actual numbers killed for the year were 8,429 blue whale units and 13,870 finbacks. pp. 318 - 319
paragraphs 0, 1, 2, 3
8. With a whale stock of reasonable size, it is a rule of thumb that 25 to 30 percent of the population can be harvested without causing a decline. pp. 319 *paragraph 4 (or 5)*
9. In response to an order by the Commission, whaling nations have stopped whaling in Temperate Zone waters (from 40 degrees North latitude to 40 degrees South latitude). pp. 320-321
paragraph 5 (or 6) and paragraph 1 (or 2)
- X 10. The Antarctic whale fishery is no longer economically significant. pp. 321 *paragraph 2 (or 1)*
- X 11. Only sharply reduced annual harvests and protective regulations that are both enforceable and enforced offer the possibility that the last of the great whales will survive. pp. 321 *paragraph 5 (or 6)*

Part III

Directions: "The Last of the Great Whales" has several graphic aids designed to aid the reader in understanding the plight of the great whales. Answer the following questions using the graphic and pictorial aids presented by the author.

1. Use the graph of PRODUCTIVITY to answer the following:
 - What happened to the whale catch from 1958 until 1964?
decline in catch
 - What happened to the number of catcher vessels from 1959 until 1961?
remained steady at over 200
 - What was the average number of blue whale units captured per catcher day in 1955?
about 1 unit/catcher day
 - If the whaling vessel Myopic operated for 50 days in 1959, how many whales did it capture?
50 whales

2. Use the graph showing the NINE-SEASON RECORD of the average length of blue whales to answer the following:
What trend is shown in the average length of blue whales captured?

decline in the average length of blue whales captured

When did whalers begin taking a larger proportion of immature whales?

1959 - 60

What was the average length of blue whales captured in 1955 and in 1963-64?

1955 = 77.2 feet 1963-64 = 70.5 feet

3. Use the graph showing the RISE AND FALL in numbers of blue and finback whales.

What does the dashed line represent? the solid line?

dashed = catch of fin back whales; solid = catch of blue whales

What might account for the fact that there is no data for several years?

World War II

As the blue whale kill declined in the fifties, what happened to the finback kill? Why?

Increase in kill of fin backs because of a shift by whalers to more numerous species.

What is now happening to the populations of blue and finbacks?

decreasing toward extinction

4. Use the bar graph of WORLDWIDE WHALE CATCH to answer the following questions:

What happened to the worldwide catch of whales from 1954 to 1961?

catch increased

How many whales has the Antarctic fishery supplied to the world catch from 1963 on?

less than half of the world's catch is now from the Antarctic

Which year saw the greatest capture of whales. How many were killed in that year?

1961 about 67,000 whales

What does the increase in the number of whales from the 1950's on reflect?

The increase reflects the anarctic fishery's growing dependence on other species (finbacks - sei whales)

5. Use the graph of CATCH RECORDS for five species to answer the following questions:

What is happening to the number of blue, humpback, and finback whales in the catch?

decreasing greatly

In spite of the decline of some species, the total number of blue whale units captured has remained high. How has this number been maintained?

Increase the take in less desirable species.

What was the total number of blue whale units killed in the 1964-65 season? What was the total number of whales killed for each of the five species listed?

1964-65 about 8,000 blue whale units

0 - humpback

20 - blue

4500 - sperm

20000 - sei

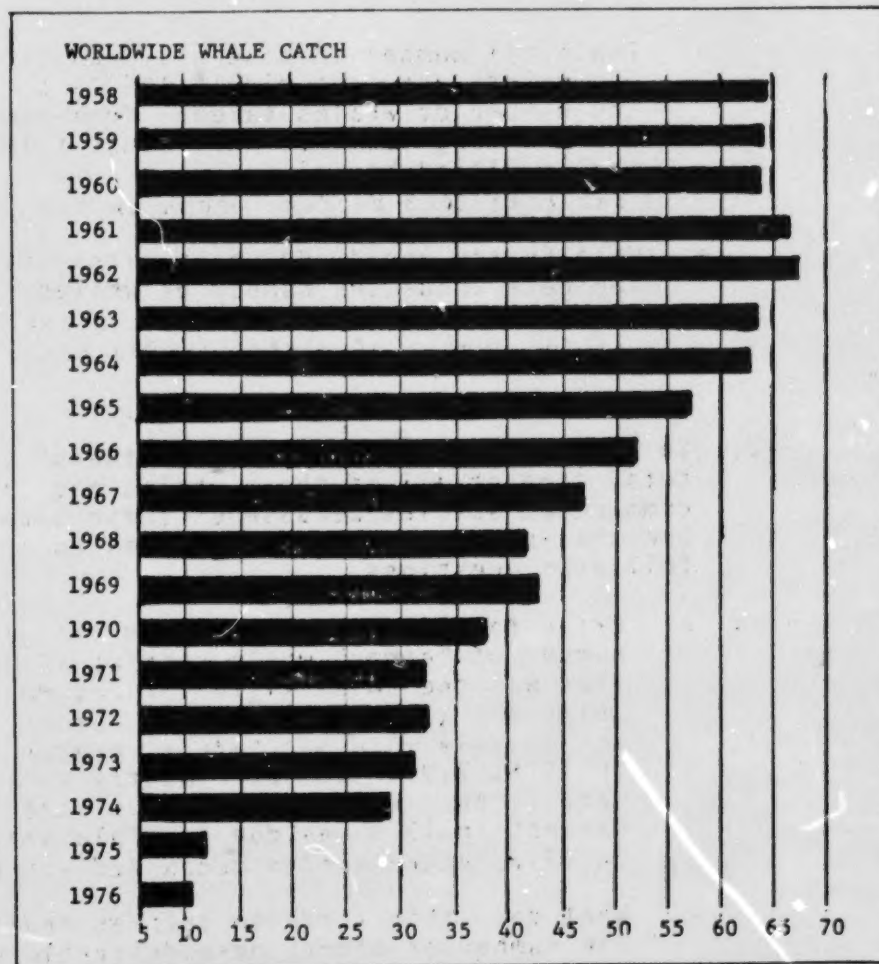
8000 - finback

Part IV

Directions: The whaling nations have had trouble agreeing with the whale commission and also agreeing among themselves over whaling policies. List three examples of this disagreement mentioned by the author.

- 1. Setting 1963 - 1964 catch limits*
- 2. protection of whales in temperate waters*
- 3. no agreement on limitation of finback kill, etc.*

One Step Further.....



- What happened to world wide whale catch from 1965 to 1977? *The catch is declining*
- Which year had the lowest whale harvest? What was the total number of whales captured in that year?
The year 1976 - 77 had the lowest whale harvest with 11,760 captured
- The 1976 - 1977 catch was about 17 % percent of the 1961 catch. This represents a reduction in whales harvested of 83% percent.

- d. The total number of blue whale units annually killed was maintained into middle 1960's by increasing the number of whales taken. From your graph, when did the long term decline in the total number of whales killed begin?

The long term decline began in the 1965-66 season.

- e. What do the worldwide whale catch statistics likely indicate about the number of whales in the seas?

The declining kills reflect a drastic reduction in the number of whales in the seas.

2. In table 1, the column marked "others" indicates the total take of all of those whales not considered commercial species because of their size or number. Use the information in this column to answer the following questions.

- a. Prior to 1976, which year had the greatest number of "other" whale species killed?
What was the total killed? Prior to 1976, the year in which the greatest number of "other whale species killed was 1968-69 when 350 "other" whales were killed.
- b. In 1976, 7,900 "others" (mostly minke whales) were taken. What percentage of the total whale harvest in 1976 was due to minke whales?
In 1976, minke whales accounted for 67% of the harvest.
- c. What does this shift in species indicate about the number of other, more desirable whales? *This shift in species indicates that the other, more desirable whales were not available for capture--we can assume they were unavailable because of overharvesting.*

3. a. Use the catch statistics in table 1 to rank the risk of extinction for the following five species of whales. Place a number 1 by the species most in danger of extinction and a 5 by the species least in danger of extinction as indicated by catch statistics.

<u>1</u>	blue
<u>3</u>	fin
<u>2</u>	humpback
<u>4</u>	sei/Bryde's
<u>5</u>	sperm

* The blue and humpback whales appear to be in about equal danger. The order of ranking is not as important as the realization that all five species are in serious trouble as indicated by catch statistics

- b. What does it mean for a species to go extinct? Will those animals ever occur again? Is man effected by the extinction of a species such as the blue whale? How?

Extinction means the species has died out. An extinct species will never occur again. Man is effected because the stability of the world ecosystem is dependent upon diversity. Every species is interconnected. It is also impossible to tell which species may hold the ultimate key to man's survival. Extinction of other organisms diminishes our chances of survival. This question is designed to provide a basis for further discussion.

- c. What does the statement "Man is a part of nature and not apart from nature" mean?

The statement means that man (we) cannot act in a way that disregards the realities of nature. We will be affected by what happens to all other organisms. Again, this is an open ended question designed to provide a springboard for further discussion.

THE LAST OF THE GREAT WHALES

SCOTT MCVAY
August 1966

The order Cetacea—the whales—consists of more than 100 species.

The 12 largest either were in the past or are now commercially important to man. At one time their oil was valued as a lamp fuel and a high-grade lubricant. Today most whale oil is made into margarine and soap, some whale meat is eaten and the rest of the animal is utilized as feed for domestic animals and fertilizer. Whale hunting is profitable, and as a result a majority of the 12 commercially hunted species have been all but exterminated. In the 18th and 19th centuries the whaling vessels of a dozen nations sailed all the oceans in pursuit of five species of whales. In that period four of the five were hunted almost to the point of extinction; the complete disappearance of these whales during the age of sail was probably prevented only by a slump in the demand for whale oil late in the 19th century. With the age of steam another seven species (which were unsuitable as quarry in the previous era) became the hunted. These species are now also in danger of extinction. It is the purpose of this article to trace the circumstances that have allowed this sorry episode to be repeated in so short a time.

The ultimate fate of the great whales has been a question for more than a century. Herman Melville included such a query among the observations that make his *Moby Dick* an encyclopedia of whales and whaling: "Owing to the al-

most omniscient look-outs at the masts of the whale-ships, now penetrating even through Behring's straits, and into the remotest secret drawers and lockers of the world; and the thousand harpoons and lances darting along all the continental coasts; the moot point is, whether Leviathan can long endure so wide a chase, and so remorseless a havoc; whether he must not at last be exterminated from the waters." Melville's conclusion was that Leviathan could endure. This was not unreasonable at the time (1851), when whalers pursued whales in open boats and killed them with lances. The five species of whales that were hunted then included only one from the suborder Odontoceti, or toothed whales; this was the sperm whale (*Physeter catodon*). The other four were baleen whales, of the suborder Mysticeti. These were the bowhead (*Balaena mysticetus*), the two right whales (*Eubalaena glacialis* and *E. australis*) and a lesser cousin, the gray whale (*Eschrichtius glaucus*). All five were hunted because they do not swim too fast to be overtaken by oarsmen and because they float when they are dead.

The bowhead whale and the right whales suffered near extinction. Very few of these once abundant animals have been seen in the past decade. In May, 1963, for example, the Norwegian ship *Rossfjord* was steaming west of the Russian island Novaya Zemlya when a whale with "jaws [that] were extremely

curved" was sighted. The event was duly noted in the *Norwegian Whaling Gazette* with the observation that the whale—clearly a right whale—belonged to "a species that the crew had not previously seen."

Today all four of these baleen whales (the gray, the bowhead and both right whales) are nominally protected by international agreement, although three right whales that were sighted in the Antarctic in the early 1960's were promptly killed and processed. Perhaps because of its gregarious way of life, the gray whale has managed a slow recovery from the pressure of hunting. An estimated 6,000 gray whales now migrate annually from the Arctic Ocean to their breeding grounds off the coast of Lower California [see "The Return of the Gray Whale," by Raymond M. Gilmore; *SCIENTIFIC AMERICAN*, January, 1955]. No one knows today how many (or how few) bowhead and right whales are still alive.

Of the eight great whales that are the quarry of modern whaling fleets, seven belong to the suborder of baleen whales and six of these to the genus *Balaenoptera* [see illustration on next two pages]. The largest of the six is the largest animal known to evolutionary history: the blue whale (*Balaenoptera musculus*). Weighing as much as 25 elephants and attaining a length of as much as 85 feet, this is the true Levi-

athan. It was known to Melville, who remarked that blue whales (he called them sulfur-bottoms) are seldom seen except in the remoter southern seas and are never chased because they can "run away with rope-walks of line." The modern catcher ship, armed with cannon-launched explosive harpoons, proved to be the blue whale's nemesis. Over the past 60 years antarctic waters have yielded more than 325,000 blue whales, with an aggregate weight in excess of 26 million tons [see "The Blue Whale," by Johan T. Ruud; SCIENTIFIC AMERICAN, December, 1956]. Even though the blue whale is now a rare animal, many of the statistics concerning baleen whales caught in the Antarctic continue to be reckoned in terms of "blue-whale units," as are the whaling nations' annual antarctic quotas.

Five other baleen whales of commercial significance are the finback whale (*Balaenoptera physalus*), the sei whale (*B. borealis*) and three smaller whales: Bryde's whale (*B. edeni*) and the two minke whales (*B. acutorostrata* and *B. bonaerensis*). The finback averages little more than 65 feet in length and yields only 10 tons of oil, compared with the blue whale's 20 tons. Accordingly in terms of blue-whale units it takes two finbacks to equal one blue. The sei is slighter, averaging 55 feet in length. It is comparatively blubber-poor and meat-rich; six sei whales equal one blue-whale unit. Bryde's whale and the minkes, the first averaging 45 feet and the other two 30 feet, are not separately identified in whaling statistics. When taken, they are probably counted as sei whales; they will receive no further mention here.

The remaining baleen whale to be taken commercially is the small but oil-rich humpback whale (*Megaptera novaeangliae*). This animal is shorter than the sei, averaging about 45 feet, but it is so stocky that it yields some eight tons of oil. Two and a half humpbacks thus equal one blue-whale unit. The humpback has evidently never existed in large enough numbers to constitute a major whaling resource. Nonetheless, until recently some 1,000 humpbacks were taken each year.

The eighth and last whale that is hunted today, surprisingly enough, is one that somehow escaped the near extermination that was the lot of the gray, bowhead and right whales in the days of sail. This is the sperm whale, which dives deep to hunt for squid along the ocean floor (its deepest-known dive is about 3,500 feet) and can remain sub-

BLUE WHALE
(*BALAENOPTERA MUSCULUS*)



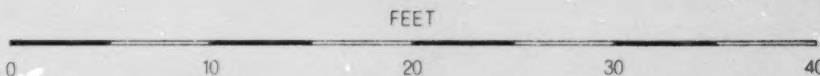
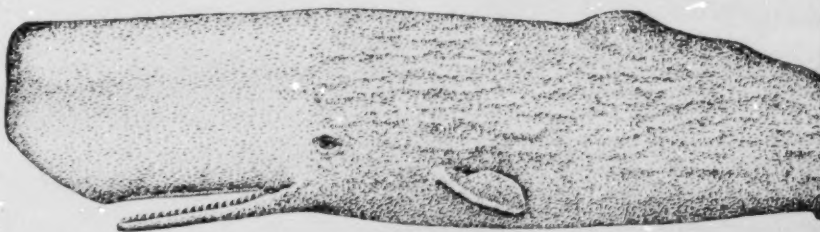
BRYDE'S WHALE
(*BALAENOPTERA EDENI*)



FINBACK WHALE
(*BALAENOPTERA PHYSALUS*)



SPERM WHALE
(*PHYSETER CATODON*)



WHALERS' QUARRY TODAY consists mainly of animals of the baleen suborder; six of the seven species are illustrated above. The blue whale, the world's largest animal, is on the verge of extinction, as is the oil-rich humpback. The finback is seriously overhunted and the same fate is befalling the sei whale. Kills of Bryde's whale and two minke whale



SEI WHALE
(*BALAENOPTERA BOREALIS*)



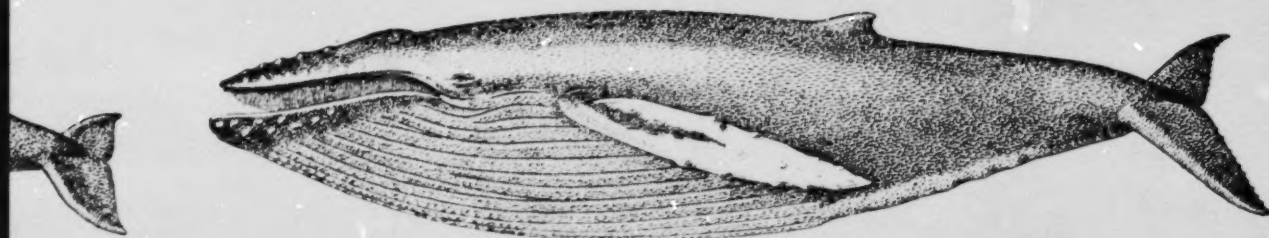
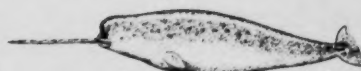
MINKE WHALE
(*BALAENOPTERA ACUTOROSTRATA*)



WHITE WHALE
(*DELPHINAPTERUS LEUCAS*)



NARWHAL
(*MONODON MONOCEROS*)



HUMPBACK WHALE
(*MEGAPTERA NOVAEANGLIAE*)

species (one of which is not illustrated) are not reported by name in the whaling statistics; they are probably counted as sei. As a result their present numbers are unknown. The toothed suborder of whales includes such familiar animals as the porpoises, the dol-

phins, the grampus, pothead and the true and false killer whales. Three of the toothed whales are illustrated. Only the largest, the sperm whale, is commercially valued and endangered by overhunting, although the narwhal and white whale are hunted occasionally.



CATCHER VESSEL pitches in a heavy antarctic swell. The stubby device seen silhouetted on the bow platform is the cannon that fires harpoons loaded with explosives. A dead whale, probably a finback, has had its flukes bobbed and is chained by its tail to the ship's side.

merged as long as 90 minutes. The sperm's huge square head contains the largest brain in the animal kingdom: it weighs more than 20 pounds. Sperm whales roam the mid-latitude oceans in groups that whalers call pods, including bulls, cows and calves. Once a year the mature bulls leave the pack and travel to antarctic waters for the summer months. As a result the whaling fleets have an opportunity to kill sperm bulls in the Antarctic and bulls and cows alike during the voyage to and from the fishery.

As the population of baleen whales in antarctic waters has dwindled, the whaling fleets have begun to spend more time in the North Pacific, where the primary quarry is the sperm whale. Every year since 1962 the industry has killed more sperm whales than whales of any other single species; the peak

catch (in 1964) was more than 29,000. Sperm whales are not counted in terms of blue-whale units, and as yet there is no limit on the number that may be taken in any year. The only limitation is on the minimum size of sperm cow that may be killed. The bowhead and the right whales, on the other hand, are supposedly protected everywhere in the world, as are the humpback and the blue whales throughout the Pacific and the humpback south of the Equator around the world.

Before World War II whaling was a *laissez faire* enterprise. Then in the postwar epoch of international cooperation 17 interested nations entered into a convention designed to regulate the whaling industry. In December, 1946, the International Whaling Commission was established as an executive body to

oversee the conservation and sensible utilization of the world's whale resources. The participating nations in the Western Hemisphere were Argentina, Brazil, Canada, Mexico, Panama and the U.S., although only Argentina and Panama were then active in the industry. (Both have since abandoned whaling.) Among the nations of Europe, Denmark, France, Britain, the Netherlands, Norway and the U.S.S.R. were signatories. So were Iceland, South Africa, Australia, New Zealand and Japan. At that time five nations operated factory ships and catcher fleets; today only Japan, Norway and the U.S.S.R. are major whaling nations. The Netherlands and Britain have abandoned their fleets, although the British continue their shore-based antarctic whaling enterprise (which is now conducted jointly with the Japanese) on the subantarctic island of South Georgia.

Since its activation in the fall of 1948 the International Whaling Commission has been charged with such tasks as protecting overexploited whale species, setting minimum-size limits below which various species may not be taken, setting maximum annual catch quotas for the antarctic fishery and designating areas closed to hunting. Although each commissioner is in principle responsible for his nation's observance of the commission's regulations, the commission itself unfortunately has neither inspection nor enforcement powers; any member nation can repudiate or simply ignore the commission's actions. Non-member nations, of course, are equally unrestricted in their whaling activities. It calls for little political insight to forecast that recommendations made by the nonwhaling members of such a body will be ignored by the whaling members. What comes as a surprise is the fact that both the whaling and the nonwhaling nations on the commission were unresponsive to the significance of the whaling statistics that were presented to them each year during the 1950's.

In the years after World War II the waters of the Antarctic constituted the world's last great whaling ground. Record catches such as the one of 1930-1931 were never repeated, but up to 1950-1951 the whalers killed some 7,000 blue whales each season. The commission's annual quota for the antarctic fishery was 16,000 blue-whale units; the catch of finbacks (at the rate of two for each blue) helped to fulfill the quota. During this period about 18,000 finbacks were killed each season [see bottom illustration on page 318].

As the 1950's progressed, however, an ominous trend was evident. The blue whales were becoming scarce. The blue-whale kill, which totaled only about 5,000 in 1951-1952, fell below 2,000 in 1955-1956 and was down to 1,200 by 1958-1959. To counterbalance the declining catch of blues, the whalers pursued the finbacks more vigorously. By the end of the 1950's, 25,000 or more finbacks were being taken each season. Those familiar with patterns of predation could see that the blue whales were being fished out and were in need of immediate full protection. The finbacks in turn probably could not survive another decade like the preceding one, during which some 240,000 animals had been subtracted from the stock.

By 1960, in spite of continued indifference on the part of the whaling nations, the commission finally decided to undertake some fact-finding. A special three-man committee was assigned the task of assessing the antarctic whale populations, even though an expert as well-regarded as the Dutch cetologist E. J. Slijper declared that the danger of their extinction was "surely remote." The committee was also to recommend any actions necessary to maintain the fishery as a continuing resource. It was agreed that, to avoid bias, the three men should be neither citizens of any nation active in antarctic whaling nor experts on whales. Three specialists in the field of population dynamics were chosen: K. Radway Allen of New Zealand, Douglas G. Chapman of the U.S. and Sidney J. Holt. Although Holt is a British subject, he has the status of an international civil servant by virtue of his employment with the Food and Agriculture Organization of the United Nations. The three men were asked to report their findings to the commission at its annual meeting in 1963.

As the special committee set about its three-year job, the world's whaling fleets continued to kill whales indiscriminately in the antarctic fishery. For the first season following the appointment of the committee the International Whaling Commission failed to set any quota for the antarctic catch. The whaling industry took more than 16,000 units that season, as well as some 4,500 nonquota sperm whales. Within the 16,000 units the catch consisted of 1,740 blue whales (510 more than the previous season) and 27,374 finbacks (a record number for kills of that species). The industry also took 4,310 sei whales, 718 humpbacks and even two

protected right whales that surfaced within range of the gunners.

During the second year of the committee's work the whaling industry did less well in the antarctic fishery. Once again the commission set no quota; the industry only managed to process 15,229 units. A few more sei and sperm whales were killed than during the previous season and another right whale was illegally shot. Among the whales that counted most—the blues and the finbacks—a larger number were immature and the numbers of both were diminishing.

The final season before the committee's report was due (1962-1963) produced a similar record. The commission set a quota of 15,000 blue-whale units. There was a modest increase in the sei and sperm kill but a sharp decline in blue and finback kills. For the first time since World War II the kill of blues fell below 1,000.

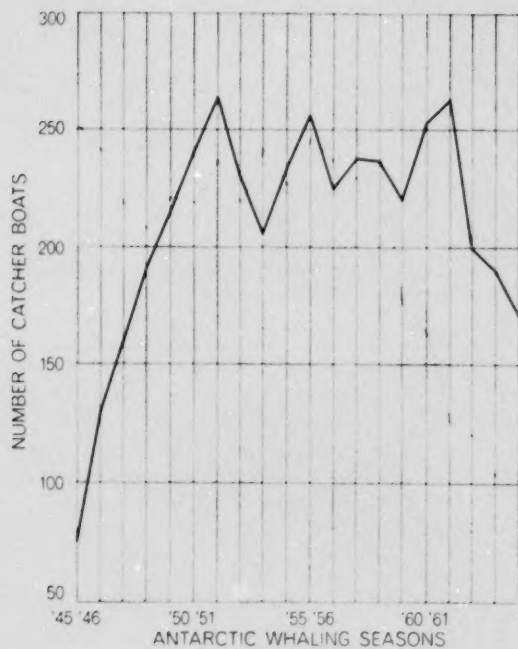
In July, 1963, the commission met in London and the special committee pre-

sented its report. The committee stated that in the antarctic fishery both the blue whale and the humpback were in serious danger of extermination. It was estimated that no more than 1,950 blue whales—possibly as few as 650—still survived in antarctic waters. The committee also noted that overfishing had reduced the stock of finbacks to approximately 40,000, far below the population level required for a maximum yield. It was recommended that the taking of blues and humpbacks be immediately prohibited and that the annual kill of finbacks be limited to 5,000 or fewer. Elimination of the blue-whale-unit system of accounting and substitution of separate quotas for each whale species was also strongly recommended.

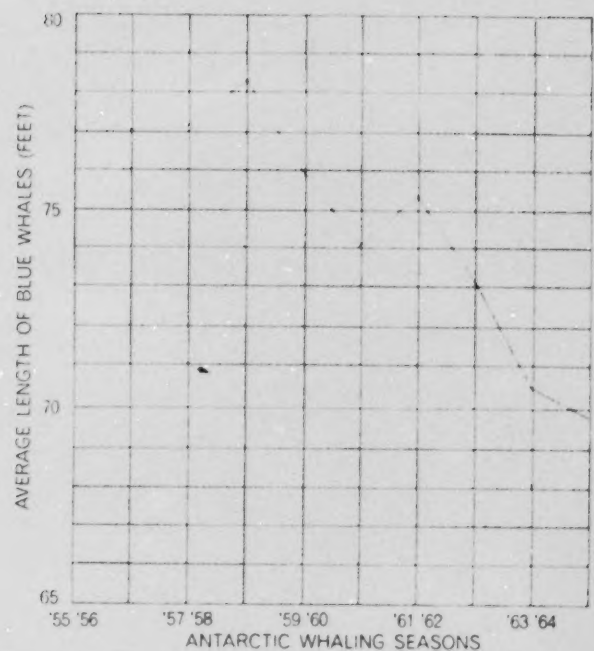
Finally the committee's three members gave the whaling industry a prediction with a clear practical meaning. They forecast that, if unrestricted whaling were permitted in the 1963-1964 season, the industry would not be able



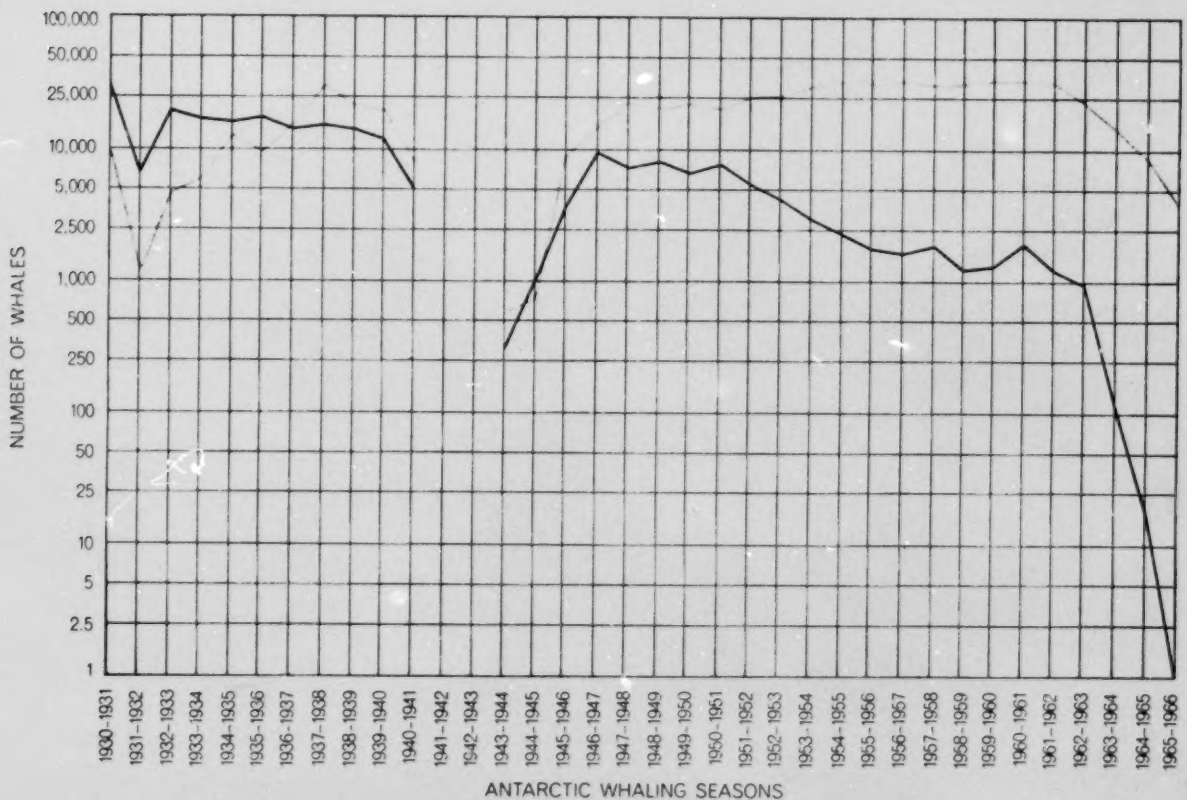
FINBACK WHALE is winched from the sea up the ramp of a factory ship. Its tongue is grotesquely expanded by the action of air that was pumped into the corpse to keep it afloat. On the flensing deck (rear) another whale is having its blubber stripped off for trying out.



PRODUCTIVITY of the antarctic fishery began a sharp decline in the late 1950's (color). The decline, measured in terms of the catch per catcher-day, continued unchecked into the early 1960's although the number of catcher vessels (black) remained well above 200.



NINE-SEASON RECORD of the average length of blue whales killed in the Antarctic shows a decline that began in the 1959-1960 season. The average mature female is 77 feet long and a mature male 74 feet. Evidently recent catches have included immature whales.



RISE AND FALL in the numbers of blue and finback whales that have been killed in the Antarctic during the past 36 years shows a correlation between the steadily diminishing blue-whale catch dur-

ing the 1950's and an increase in the catch of finbacks (color). Just as the blue-whale stock dwindled away under the pressure of overhunting, the finback stock is now showing a severe decline.

to harvest more than 8,500 blue-whale units and would slaughter 14,000 finbacks—nearly three times the recommended number—in the process.

The prediction was disregarded. The commission voted a 1963–1964 quota of 10,000 blue-whale units for the antarctic fishery on a motion by the Japanese commissioner that was seconded by the Russian commissioner. In view of the committee's predicted maximum catch this was in effect no quota at all.

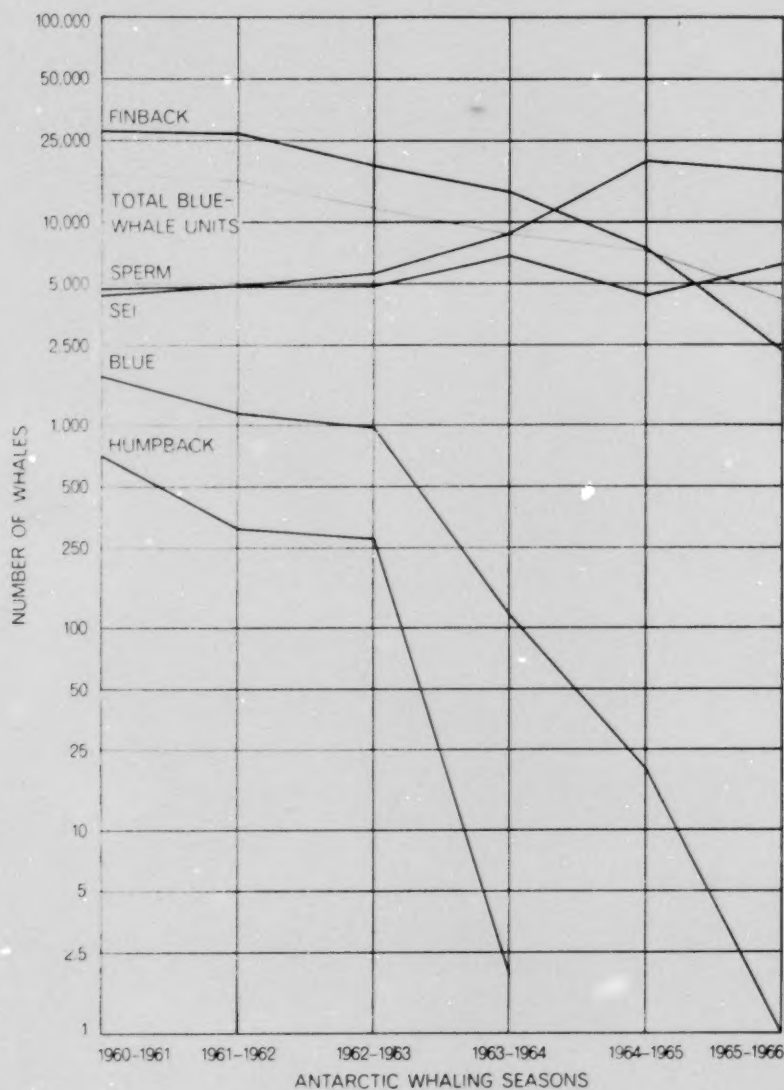
As for the committee's other findings, the commission failed to act on some and was lukewarm toward others. In the case of the now economically insignificant humpback, the commission could afford to be forthright; that whale was declared protected anywhere in the world south of the Equator. In the case of the blue whale a partial sanctuary was established in all waters south of 40 degrees south latitude except some 3.3 million square miles from 40 to 55 degrees south latitude and from the Greenwich meridian to 80 degrees east longitude. Japanese whalers had taken some 700 small blue whales in this zone during the 1962–1963 season; they considered it too good a hunting ground to be put out of bounds. The suggested elimination of the blue-whale unit and the establishment of species quotas were ignored. The commission added a fourth man (John A. Gulland of Great Britain) to the special committee and asked that a further report be presented in 1964. At that time it was intended to set the antarctic quota at a level in line with the committee's findings.

In 1963 a few members of the commission may have viewed with skepticism the ability of the three committee members to make accurate forecasts of a phenomenon as full of variables and unknowns as the effects of harvesting the antarctic whale stock. If so, the results of the 1963–1964 season settled their doubts. Sixteen factory ships and their catcher fleets worked the fishery; the industry's statistics, weighing such factors as the number of days each catcher was able to spend in hunting, showed that the total effort of the catchers was 91 percent of that during the season of 1962–1963. The number of blue whales killed, however, was the lowest of any season in the industry's history: a mere 112. The committee had predicted a total catch of 8,500 blue-whale units; the fleet managed to process 8,429 units. The committee had predicted that 14,000 finbacks would be killed; the finback toll came to 13,870.

The committee's forecasts thus proved to be highly accurate.

At the commission's 1964 meeting the enlarged committee added the sei whale, formerly the least prized of any in the antarctic fishery, to the list of the overhunted. The committee pointed out that the total sei population had probably never exceeded 60,000, yet more than 20,000 sei had been killed in the course of the four previous seasons. With a whale stock of reasonable size it is a rule of thumb that 10 to 15 percent of the population can be harvested annually without causing a decline. With the expectation that more and

more sei whales would be killed each season as the finback population thinned out, the committee anticipated sei kills above the sustainable level in the immediate future. In line with the commission's declared intention of setting quotas according to the committee's findings, it was proposed that the antarctic quota be drastically reduced in three annual steps. A limit of 4,000 units was sought for the 1964–1965 season, a limit of 3,000 units for 1965–1966 and one of 2,000 units for 1966–1967. This degree of restraint, the population experts declared, was necessary merely to hold the number of whales in the Antarctic at the present level. They once more ap-



CATCH RECORDS for five species of whales killed in the Antarctic during the past six seasons show that increasing catches of sperm and sei whales have failed to counterbalance the decline in the fishery's productivity. The yield, calculated in blue-whale units (color), has dropped from 16,375 units in 1960–1961 to one-quarter of that amount in 1965–1966.

pealed—once more unsuccessfully—for the establishment of species quotas in place of the blue-whale-unit system.

Finally, a new gloomy statistic came before the commission: in 1963, for the first time since modern whaling had begun in the Antarctic, the larger part of the world catch had been taken in

other waters. The most heavily fished area had been the North Pacific; most of the whales taken there had been sperm, which continued to be free of quota restrictions. The committee pointed out that this diversion of the industry's effort from the dwindling antarctic whale resource to the North Pacific

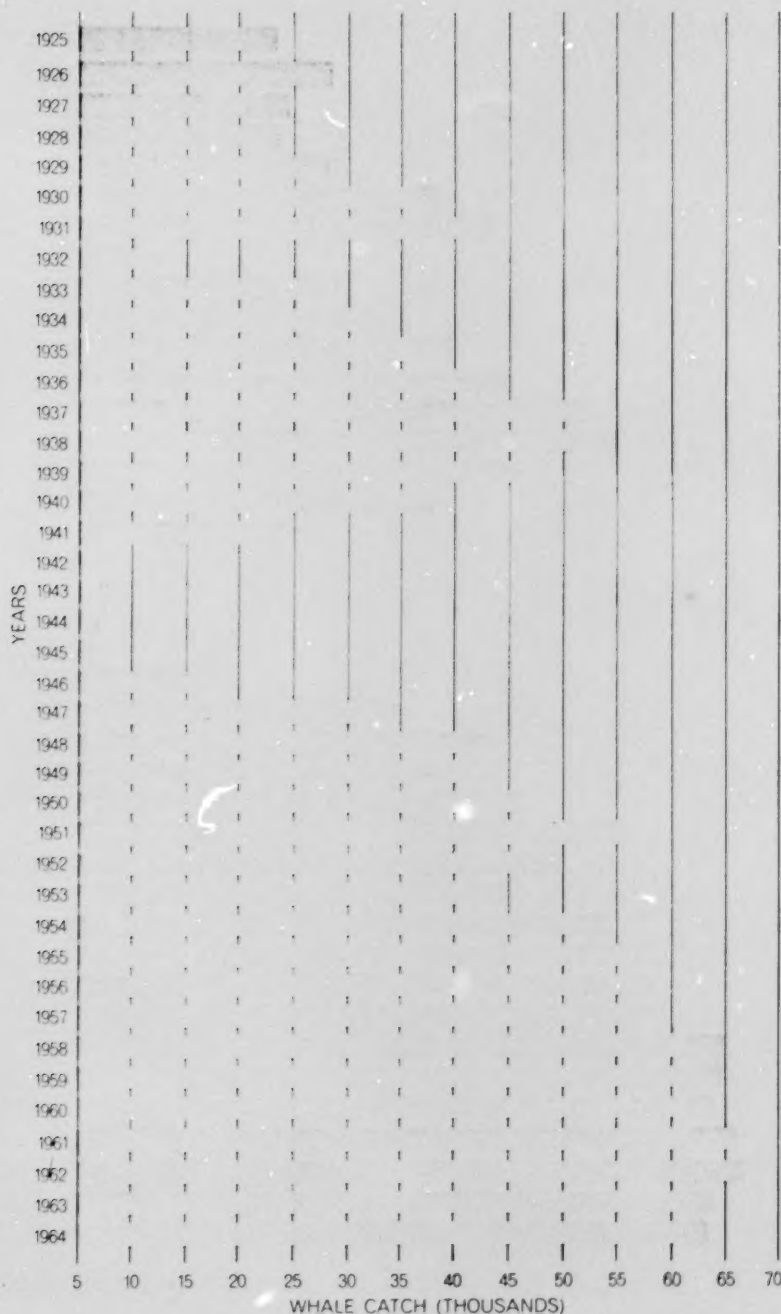
could have ominous consequences for the sperm-whale stock.

The proposal for a reduced antarctic quota came to a vote in the commission. Japan, the U.S.S.R., Norway and the Netherlands all voted against it; in spite of the commission's declared intent to give substance to the committee's findings, the 1964 meeting adjourned with no commission quota set for the next antarctic season. The four whaling nations subsequently agreed in private that they would limit themselves to 8,000 blue-whale units in the 1964–1965 season, a figure twice the one recommended by the committee.

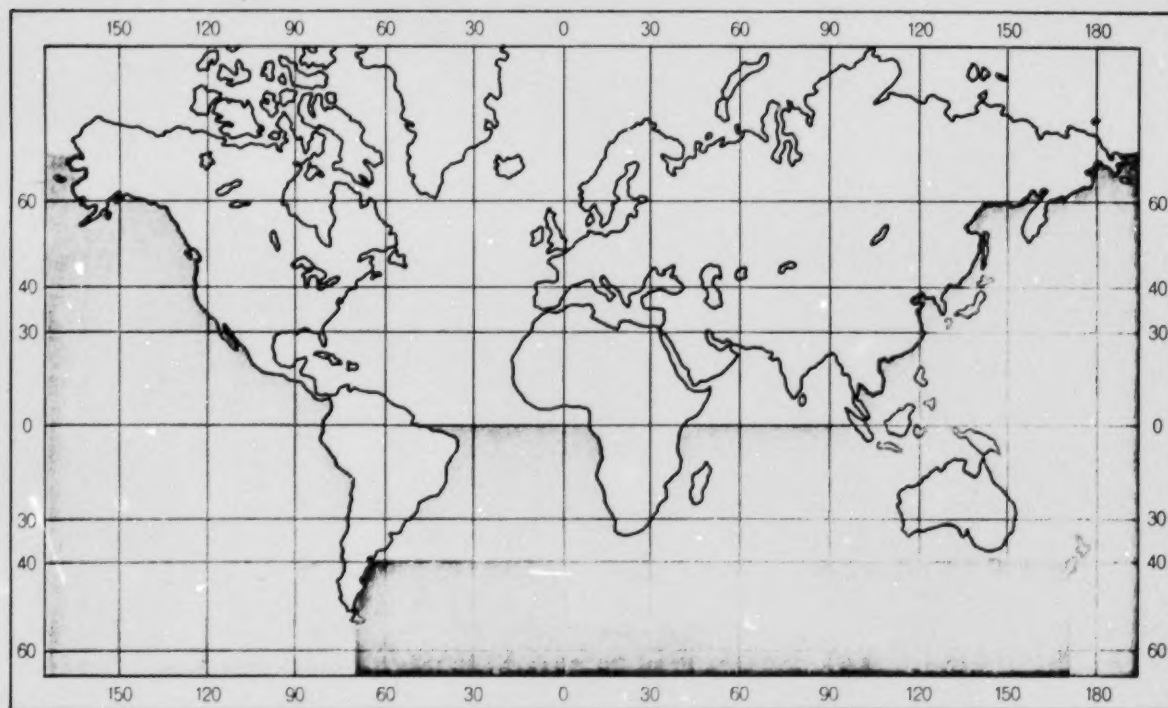
The 1964–1965 season was disastrous. The industry processed only 7,052 units, more than 10 percent short of its self-established quota. Only 20 blue whales were killed. The finback kill, declining for the fourth successive year, was 7,308 animals, or only a quarter of the 1960–1961 peak. As the committee had anticipated, the industry made up the difference by overkilling sei whales—almost 20,000 of them. In spite of this slaughter and a fairly large nonquota sperm-whale catch, the antarctic fishery for a second year supplied the industry with fewer whales than were taken in other waters.

For the first time since the beginning of the crisis the International Whaling Commission convened a special meeting. At this meeting (in May, 1965) the commission established a quota for the 1965–1966 antarctic season that reflected, at least in part, the committee's concern. The catch, even the whaling nations agreed, should not exceed 4,500 blue-whale units. At the regular June meeting that followed, the reduced quota was approved, and the commission agreed on a plan for further successive reductions of the antarctic fishery's quotas in the seasons to come.

The commission also attempted a first step toward partial protection of the world's sperm-whale stock. Up to that time the only restriction governing sperm kills was that cows less than 38 feet in length should not be taken. In 1964 the worldwide sperm catch had risen to a high of more than 29,000. The fleets en route to and from the Antarctic had killed 4,316 sperm whales. Once they were in the antarctic fishery they had taken 4,211 more; most of the rest had been killed in the North Pacific. In the hope of protecting sperm cows in Temperate Zone waters the commission ordered a worldwide hunting ban in the area between



WORLDWIDE WHALE CATCH during the 40-year period through 1964 exceeded 1.6 million animals. The increase in numbers of whales taken from the 1950's on reflects the antarctic fishery's growing dependence first on finbacks in lieu of blue whales and next on sei whales in lieu of finbacks. From 1963 on the antarctic fishery has provided less than half of the world's whale catch. Figures are from Norway's Bureau of International Whaling Statistics.



REFUGE AREAS within which designated species of whales are safe from hunting by member nations of the International Whaling Commission have been expanded in recent years. The nearly extinct bowhead and right whales enjoy worldwide protection. The blue and humpback whales are protected throughout the Pacific.

The humpback is also protected south of the Equator elsewhere in the world, but the blue whale's protection elsewhere is limited to a zone south of 40 degrees south latitude (gray area). Even within this zone of protection 3.3 million square miles of ocean were kept open for blue-whale hunting at the request of Japan until a year ago.

40 degrees north latitude and 40 degrees south latitude. All three whaling nations, however, objected to the commission's order; the ban has simply been ignored. The worldwide sperm catch in 1965 was somewhat lower than in 1964; future catch records will reveal whether or not this drop reflects overkilling.

The imperative need for a reduced antarctic quota was demonstrated clearly enough by the results of the 1965-1966 season. With a quota of 4,500 blue-whale units the antarctic fleets could process only 4,089 units. The finback kill reached a new low, less than 10 percent of the 1960-1961 peak; in spite of protection, one blue whale and one humpback were taken. Again it was the sei whales that bore the brunt of the slaughter, and even their numbers were less than in the previous season. The conclusion was inescapable: The antarctic fishery, with its seasonal yield down to less than 100,000 tons of oil, was no longer economically significant.

Can the antarctic whale fishery ever be restored? Even with the progressively reduced quotas now envisioned it may take 100 years before this resource

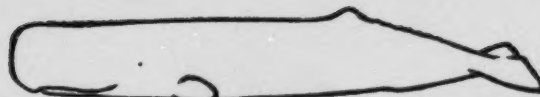
recovers to the level of the middle 1950's. Recovery to the levels before World War II, which depended almost exclusively on the blue whale, is improbable. This giant mammal—one of the most remarkable ever to appear on the earth—has probably been reduced in numbers below the level that allows a species to survive; its worldwide population today may well be less than 1,000. Certainly there are 594 fewer blue whales this year than last. Whaling from land stations in Peru and Chile—two nations that are not parties to the international convention—accounted for 449 of these casualties in 1965.

The crucial question today does not concern the antarctic fishery but rather the future of all whaling. Continued overhunting of the finback whale can be expected to do to that species what has already been done to the blue whale. Last year, in addition to the antarctic season's kill of 2,314 finbacks, roughly 4,500 more of these animals were taken in other waters. Throughout the world's oceans today the only great whale that survives in economically significant numbers is the sperm. Yet a measure of the industry's lack of concern for its dwindling resources may be

gained from recent efforts to establish quotas in the North Pacific, where the absence of quotas or restrictions allows hunting all year long. In spite of efforts by Canada and the U.S. the two whaling nations with fleets in the North Pacific—the U.S.S.R. and Japan—could not even agree to restrict the finback kill, let alone that of either sei or sperm.

Each of two past eras of whaling has virtually eradicated its own most highly prized whale species. The bowhead whale and the right whales are monuments to man's thoughtlessness in the days of sail. The blue whale and humpback—and possibly the finback and sei as well—are monuments to an industry's lack of foresight in the days of steam. The whaling nations today face a third and almost certainly a final decision. If essentially unrestricted whaling continues, the only surviving stock of any economic importance—the sperm whale, of whose numbers more than 250,000 have been killed in the past 12 years—is doomed to become a monument to international folly. Only sharply reduced annual harvests and protective regulations that are both enforceable and enforced offer the possibility that the last of the great whales will survive.

THE LAST OF THE GREAT WHALES



Part I - Preview

Directions: Before you read the article, preview "The Last of the Great Whales" by scanning the article to find the answers to the following questions.

1. What is the title and who is the author of this article?
2. How many figures are there in this article? How many of these are graphs?
3. What do you think this article is going to deal with?

Part II

Directions: Read the following statements carefully. Check those statements that are actually stated or paraphrased in the story. Be ready to explain what is inaccurate about the statements that you do not check. After the statement, write the page number and paragraph number which gives you support for your choices.

- _____ 1. The purpose of the article is to trace the circumstances that led to the near extinction of about 12 species of whale.
- _____ 2. Right whales gained their name because, when hunted, they can always be expected to sound (dive) to the right rather than to the left.
- _____ 3. Statistics related to whale capture are measured in 'Blue Whale Units'.
- _____ 4. Decreasing numbers of whales in Anarctic waters have caused the whaling fleets to spend more time in the North Pacific and other whaling regions.
- _____ 5. The International Whaling Commission which oversees the conservation and sensible utilization of the world's whale resources has both inspection and enforcement powers.
- _____ 6. Declining catches of blue whales resulted in the more vigorous pursuit of finbacks.

- _____ 7. For the 1963-64 season, the Commission forecast that if unrestricted whaling were permitted, the industry would not be able to harvest more than 8,500 blue whale units and would slaughter 14,000 finbacks in the process. The actual numbers killed for the year were 8,429 blue whale units and 13,870 finbacks.
- _____ 8. With a whale stock of reasonable size, it is a rule of thumb that 25 to 30 percent of the population can be harvested without causing a decline.
- _____ 9. In response to an order by the Commission, whaling nations have stopped whaling in Temperate Zone waters (from 40 degrees North latitude to 40 degrees South latitude).
- _____ 10. The Antarctic whale fishery is no longer economically significant.
- _____ 11. Only sharply reduced annual harvests and protective regulations that are both enforceable and enforced offer the possibility that the last of the great whales will survive.

Part III

Directions: "The Last of the Great Whales" has several graphic aids designed to aid the reader in understanding the plight of the great whales. Answer the following questions using the graphic and pictorial aids presented by the author.

1. Use the graph of PRODUCTIVITY to answer the following:
What happened to the whale catch from 1958 until 1964?

What happened to the number of catcher vessels from 1959 until 1961?

What was the average number of blue whale units captured per catcher day in 1955?

If the whaling vessel Myopic operated for 50 days in 1959, how many whales did it capture?

2. Use the graph showing the NINE-SEASON RECORD of the average length of blue whales to answer the following:
What trend is shown in the average length of blue whales captured?

When did whalers begin taking a larger proportion of immature whales?

What was the average length of blue whales captured in 1955 and in 1963-64?

3. Use the graph showing the RISE AND FALL in numbers of blue and finback whales.

What does the dashed line represent? the solid line?

What might account for the fact that there is no data for several years?

As the blue whale kill declined in the fifties, what happened to the finback kill? Why?

What is now happening to the populations of blue and finbacks?

4. Use the bar graph of WORLDWIDE WHALE CATCH to answer the following questions:

What happened to the worldwide catch of whales from 1954 to 1961?

How many whales has the Antarctic fishery supplied to the world catch from 1963 on?

Which year saw the greatest capture of whales? How many were killed in that year?

What does the increase in the number of whales from the 1950's on reflect?

5. Use the graph of CATCH RECORDS for five species to answer the following questions:

What is happening to the number of blue, humpback, and finback whales in the catch?

In spite of the decline of some species, the total number of blue whale units captured has remained high. How has this number been maintained?

What was the total number of blue whale units killed in the 1964-65 season? What was the total number of whales killed for each of the five species listed?

Part IV

Directions: The whaling nations have had trouble agreeing with the whale commission and also agreeing among themselves over whaling policies. List three examples of this disagreement mentioned by the author.

ONE STEP FURTHER

What has happened to whales and whaling since "The Last of the Great Whales" was published? Because worldwide catch figures usually are not immediately available we cannot offer completely current figures. The figures below partially update the data in "The Last of the Great Whales". Use the figures to answer the following questions:

Table 1 shows the whales killed by species from 1965 to 1977.

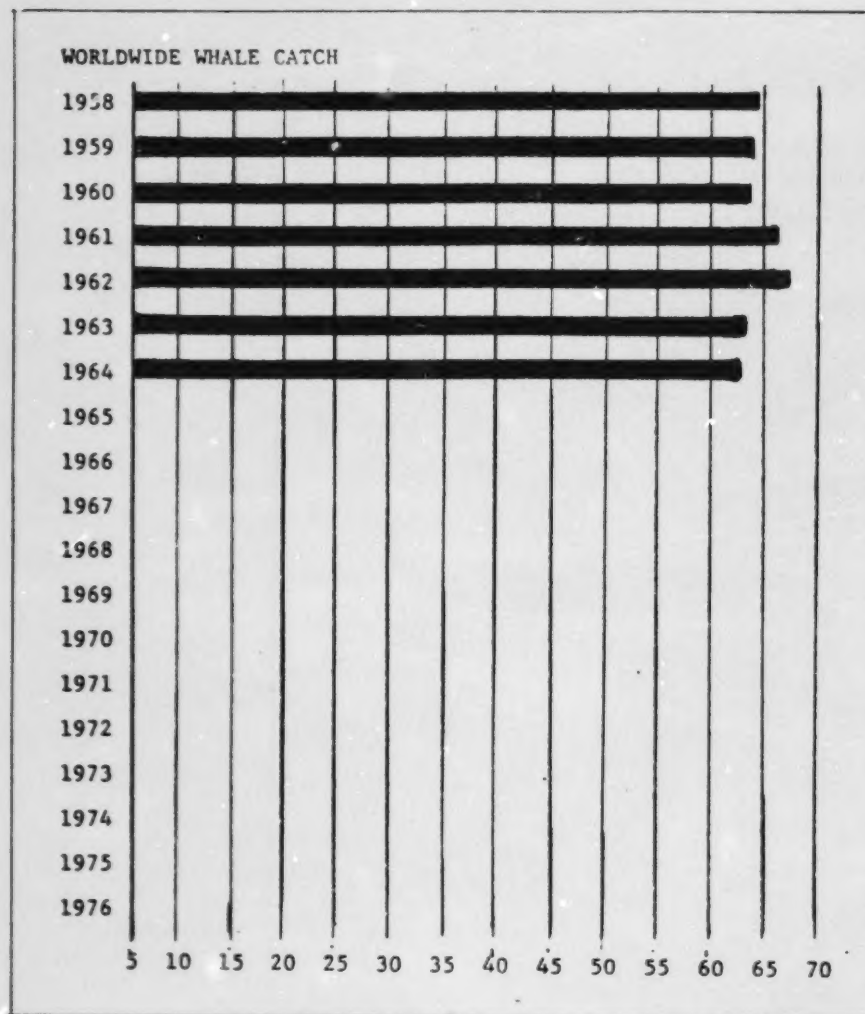
TABLE I: Whales killed by species, 1965 - 1977

Year	Blue	Fin	Humpback	Sci/Bryde's	Sperm	Others	Total
1965-66	243	6,882	59	23,067	27,378	262	57,891
1966-67	70	6,458	4	19,016	26,424	266	52,238
1967-68		5,268	2	19,960	24,080	335	46,645
1968-69		5,355	9	12,483	23,929	350	42,126
1969-70	1	5,237	15	11,561	25,521	146	42,481
1970-71	9	4,572	24	11,372	22,642	152	38,771
1971-72		4,192	6	8,819	18,895	221	32,133
1972-73	7	2,620	15	7,439	22,305	216	32,602
1973-74		2,129	9	8,062	21,134	204	31,538
1974-75		1,427	9	6,826	20,726	191	29,179
1975-76*		206	-	1,821	9,875	n/a	11,902
1976-77*	0	0	0	1,858	2,002	7,900**	11,760

*Figures for Antarctic only.

**Minkes only.

1. The bar graph below is taken from the article by Scott McVay. Add the total figures from Table 1 to the bar graph.



- a. What happened to worldwide whale catch from 1965 to 1977?
- b. Which year had the lowest whale harvest? What was the total number of whales captured in that year?

- c. The 1976-1977 catch was _____ percent of the 1961 catch. This represents a reduction in whales harvested of _____ percent.
 - d. The total number of blue whale units annually killed was maintained into the middle 1960's by increasing the number of whales taken. From your graph, when did the long term decline in the total number of whales killed begin?
 - e. What do the worldwide whale catch statistics indicate about the number of whales in the seas?
2. In table 1, the column marked "others" indicates the total take of all of those whales not considered commercial species because of their size or number. Use the information in this column to answer the following questions.
 - a. Prior to 1976, which year had the greatest number of "other" whale species killed? What was the total killed?
 - b. In 1976, 7,900 "others" (mostly minke whales) were taken. What percentage of the total whale harvest in 1976 was due to minke whales?
 - c. What does this shift in species indicate about the number of other, more desirable, whales?
 3. a. Use the catch statistics in table 1 to rank the risk of extinction for the following five species of whales. Place a number 1 by the species most in danger of extinction and a 5 by the species least in danger of extinction as indicated by catch statistics.
 - _____ blue
 - _____ fin
 - _____ humpback
 - _____ sei/Bryde's
 - _____ sperm

- b. What does it mean for a species to go extinct? Will those animals ever occur again? Is man effected by the extinction of a species such as the blue whale? How?

- c. What does the statement "Man is a part of nature and not apart from nature" mean?

BIOLOGICAL FACTORS:

Current Issues

TEACHER BACKGROUND - The Worst Oil Spill? - Sequencing Guide

As the number and size of oil tankers increase, the likelihood of disastrous oil spills also increases. In a recent three year period over the world at large, tankers were involved in potentially serious accidents on an average of about twice a week. Near dawn on Wednesday, December 15, 1976, the Liberian tanker Argo Merchant went aground on Fishing Rip, an area of treacherous shoals 29 nautical miles southeast of Nantucket. Within a few hours, the U.S. Coast Guard Atlantic and Gulf Strike Teams were on the scene, attempting to refloat the stricken ship and prevent its cargo of 7.7 million gallons of number 6 fuel oil from spilling into the sea.

But the Argo Merchant remained aground, and buffeted by rough seas and high winds, began to leak oil that afternoon. Attempts to off-load the ship's cargo were thwarted by heavy weather, and the tanker continued to leak. At 8:35 a.m. on December 21, the battered vessel began to break up, spilling virtually all of its oil into the rough waters off Massachusetts. The grounding of the Argo Merchant had become one of the largest oil spills in United States History.

The article which follows is taken from a Newsweek magazine from published following the sinking. It gives a good overview of the potential for disaster locked in every oil spill. A sequencing activity follows. Sequencing is a skill important in reading and science. The activity gives your students practice in this skill while reinforcing the concepts highlighted in the article.

Duplicate the article and the activity pages. One set is recommended per student. This activity is best accomplished by individual students as homework or as an in-class assignment. After initial individual work, you may have your students meet in small groups to come to a consensus before you discuss the activity with your class. Regardless of the teaching approach you select, plan to provide an opportunity for a class discussion of the materials.

KEY

A completed sequencing guide follows the "KEY WORDS" section.

KEY WORDS

chronological

consolation

food web

glutinous

gyrocompass

ingest

metabolism

plankton

sequence

significant

slick

tainted

toxins

The Worst Oil Spill

The following events have occurred or are likely to occur according to the information found in the article "The Worst Oil Spill?". Arrange the events in the proper chronological (time) sequence by placing a number 1 in front of the first event, and so on.

- 7 At best a significant part of the annual 485,000 ton catch of flounder, cod, scallops, lobsters, and other food fish could be lost in five years' time...
- 4 The slick covered an area up to 44 miles wide and 141 miles long posing the threat of an ecological disaster.
- 5 Under the continual battering of the winter waves, the flat, glutinous "pancakes" that make up the bulk of the slick will split up into tar balls whose sizes will vary from that of a 50-cent piece to that of a trash barrel.
- 9 The Argo Merchant's skipper admitted that his vessel was more than 24 miles off course when it went aground and that its gyrocompass was not working at the time of the accident.
- 6 Plankton, sand and ocean debris will slowly collect on the tar balls, increasing their density and causing them to sink.
- 2 The Coast Guard lost \$200,000 worth of equipment that it had installed on the Argo Merchant before the vessel broke in two.
- 1 The Argo Merchant's 7.6 million gallons of number 6 fuel oil are spilled into the sea after the vessel runs aground off Nantucket Island.
- 3 At one stage the Coast Guard burned off a test area of the slick about 25 feet in diameter.
- 8 Two groups of New England fishermen filed suits for a total of \$120 million in damages against the owners of the vessel.
- 10 If environmentalists could find one note of consolation, it was that the sinking of the Argo Merchant seemed certain to focus renewed attention on tanker safety.

Part II

Howard Sanders of the Woods Hole Oceanographic Institution outlines a possible outcome of the oil spill. Place his following statements in the proper sequence:

- 3 Fish heartbeats will increase, their metabolisms will speed up.
- 1 Tiny plants and animals living on the sea bottom will ingest the toxins from the oil.
- 4 Fish growth will be stunted because they will have to expend most of their energy simply staying alive.
- 6 One complete link in the food web could be destroyed, upsetting the ecological balance of the area.
- 5 The fish will reproduce less often, and their offspring may turn out to be weaker than normal.
- 2 Fish will consume the tainted organisms and start to react to the oil-based poisons.

Part III

The diagram which runs across pages 74 and 75 outlines some possible events resulting from the incident described in the article. In the space below, list the events mentioned in their order of occurrence.

1. Argo Merchant is wrecked.
2. Wind induced currents carry oil slick away from coast.
3. Globs of oil sink.
4. Bottom currents push sunken globs of oil toward New England coastline.

The Worst Oil Spill?

Viewed from the cockpit of a U.S. Coast Guard spotter plane flying at 5,500 feet, the vast oil slick off Nantucket Island glittered evilly, like an enormous stain of phosphorescent glue spread out over the stormy waters of the Atlantic. On a shoal just 27 miles southeast of Nantucket, 20-foot-high waves pounded ceaselessly at the hulk of the wrecked Liberian-registered tanker Argo Merchant. Each time the water crashed into the hull, more gouts of heavy No. 6 industrial fuel oil gushed out. Soon, almost all of the Argo Merchant's cargo of 7.6 million gallons of oil would be spilled into the sea.

Already, the slick covered an area up to 44 miles wide and 141 miles long, and it posed the threat of an environmental disaster of enormous magnitude: economic ruin for many fishermen along the New England coast and hard times for the area's multimillion-dollar summer tourist industry. For the moment, fishermen and residents in the threatened area took what comfort they could from the fact that the oil slick seemed to be moving out to the open sea. But the experts—U.S. Coast Guard officials, National Marine Fisheries Service biologists and scientists at the University of Rhode Island—said that even if the huge spill should be carried out to sea, the aftereffects in the immediate area could still be immense and long-lasting. At best, a significant part of the annual 485,000-ton catch of flounder, cod, scallops, lobster and other food fish could be lost in five years' time; at worst, much of the Georges Bank spawning ground, perhaps the richest in the world, could be temporarily destroyed.

Experts think that they know how the slick will eventually break up. First, under the continual battering of the winter waves, the flat, glutinous "pancakes" that make up the bulk of the slick will split up into tar balls whose sizes will vary from that of a 50-cent piece to that of a trash barrel. Plankton, sand and

ocean debris will slowly collect on the tar balls, increasing their density and causing them to sink. What is critical to the fate of the New England fishing industry is how far the slick will travel before the tar balls start to sink. The effects will be worst if a substantial part of the oil sinks before it travels beyond the relatively shallow waters of the continental shelf (diagram).

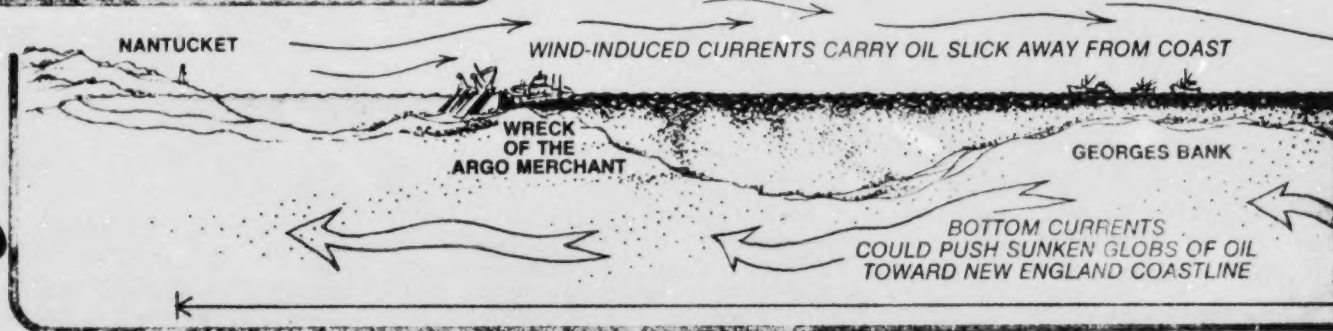
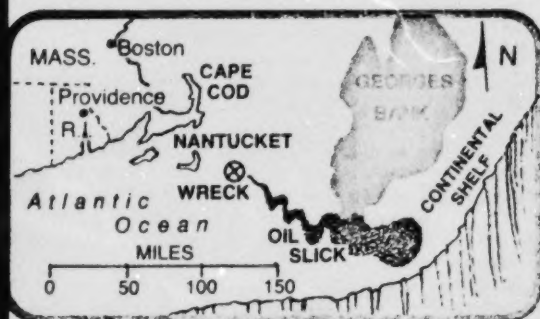
At present, the most endangered creatures—apart from sea birds whose feathers are begrimed with oil—are the larvae of the region's huge population of finfish—cod, pollock, haddock, yellowtail, flounder and halibut. After these fish spawn, their larvae float up to the surface. If they encounter oil there, the larvae will simply smother to death. Marine biologists fear that the oil could wipe out a substantial portion of the 1976 fish hatch, and thus cause a massive reduction in the "year class" of 1981, when the survivors among this year's larvae will be harvested.

Toxins: But the impact of a decrease in the finfish catch in half a decade appears minor when compared with the damage that could be caused if the bulk of the oil sinks onto the continental shelf. According to Howard Sanders of the Woods Hole Oceanographic Institution, the oil will embed itself in the sediment on the bottom and then start to degrade slowly, giving off toxic chemicals in the process. That will trigger a textbook example of ecology in action.

First, tiny plants and animals living on the sea bottom will ingest the toxins from the oil. Then fish will consume the tainted organisms and start to react to the oil-based poisons. Their heartbeats will increase; their metabolisms will speed up; their growth will be stunted, because they will have to expend most of their energy on simply staying alive; they will reproduce less often, and their offspring may turn out to be weaker than normal. Conceivably, one complete link in the marine food chain could be destroyed in this way, causing, over a number of years, an upset of the area's ecological balance.



Argo Merchant's slick: Where will it sink?



The damage would not be restricted to finfish. Large scallop beds could be covered by the oil, and lobsters would start to ingest the pollution. "The lobster would become too tainted for human consumption," says Lee Bridges of the National Marine Fisheries Service. Even if the lobsters remained safe to eat, consumers might shy away as a result of the spill, upsetting a \$52.5 million-a-year industry. Vacationers would also suffer if the oil sinks too close to shore. Driven by the bottom currents, the tar would inevitably drift up on beaches, ruining bathing suits and burning the skin of bathers.

Precautions: At the moment, scientists think there is appreciably less than a 50-50 chance that a substantial amount of the oil will sink before it reaches the edge of the continental shelf, but they point out that occasional shifts in wind direction, which are causing the slick to slosh to and fro like water in a bathtub, might break up the pancakes sooner than expected. As a precaution, pilots from the Coast Guard and the National Oceanic and Atmospheric Administration have dropped thousands of small orange plastic cards between the spill and the mainland. "If anybody runs across one of these drift cards lying on the beach," explained Jim Mattson, who headed the effort, "it will give us an eight- to twelve-hour warning that the oil is coming." In case that does happen, crews have been stationed to deploy booms to surround the oil once it reaches the calmer waters near shore.

Very little else can be done to contain or destroy the oil. The Coast Guard lost \$200,000 worth of equipment that it had installed on the Argo Merchant before the vessel broke in two—and it was unable to position plastic booms to surround the slick owing to the height of the waves. "The wind and sea conditions were far beyond what our equipment could handle," said Coast Guard Capt. Frederick Schubert.

Experts also vetoed the use of emulsifiers and detergents to disperse and sink the slick, because of evidence from other major spills that these chemicals might cause even more damage to marine life than the oil. At one stage the Coast Guard burned off a test area of the slick about 25 feet in diameter, using a combustible chemical and flares. But it is impossible to burn the bulk of the

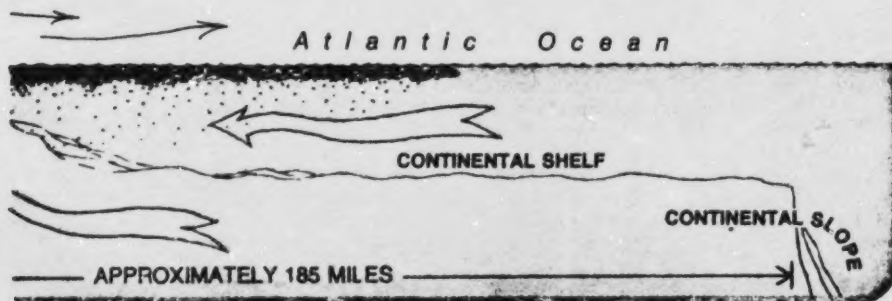
spill because by now much of the oil is separated into huge pancakes riding 3 to 4 inches beneath the surface.

Even as state and Federal government officials waited tensely for news of the slick's movements, another Liberian-registered tanker went aground in the Delaware River off Marcus Hook, Pa., spilling 134,000 gallons of oil and posing a direct threat to thousands of duck, geese and other waterfowl in the estuary. That spill was the fourth major tanker accident since mid-December. On Dec. 17, the just-emptied Liberian-registered tanker Sansinena exploded at Long Beach, Calif., killing nine people and injuring more than 50. On Christmas Eve, about 2,000 gallons of oil leaked from the tanker Oswega-Peace in Connecticut's Thames River and fouled miles of riverbank.

Action: The Argo Merchant disaster rapidly wound up in Federal Court. Two groups of New England fishermen filed suits for a total of \$120 million in damages against the Thebes Shipping Co., the Liberian-based Greek corporation that owns the vessel. The Argo Merchant's owners hit back, seeking to limit their liability to the value of the ship and its cargo—which now stands at exactly zero. In testimony in New York last week, the Argo Merchant's skipper, Capt. Georgios Papadopoulos, admitted that his vessel was more than 24 miles off course when it went aground and that its gyrocompass was not working at the time of the accident.

If environmentalists could find one note of consolation, it was that the sinking of the Argo Merchant seemed certain to focus renewed attention on tanker safety. Environmental Protection Agency administrator Russell E. Train expressed anger at the reluctance of the Federal government to order stricter construction standards, especially the requirement of double bottoms for foreign-registered oil tankers. Cecil Andrus, Interior Secretary-designate, said that the incoming Carter Administration is "acutely aware" of the problems surrounding the transportation of oil to the U.S.—and environmentalists, fishermen and ordinary citizens could only hope that prompt action would be taken to prevent more disasters like the wreck of the Argo Merchant.

—PETER GWYNNE with RICHARD MANNING in Kingston, R.I., and JEFF B. COPELAND in Washington



January 10, 1977



Drawings by Ib Ohlsson

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The Worst Oil Spill?- Sequencing Guide

The following events have occurred or are likely to occur according to the information found in the article "The Worst Oil Spill?". Arrange the events in the proper chronological (time) sequence by placing a number 1 in front of the first event, and so on.

- _____ At best a significant part of the annual 485,000 ton catch of flounder, cod, scallops, lobsters, and other food fish could be lost in five years' time...
- _____ The slick covered an area up to 44 miles wide and 141 miles long posing the threat of an ecological disaster.
- _____ Under the continual battering of the winter waves, the flat, glutinous "pancakes" that make up the bulk of the slick will split up into tar balls whose sizes will vary from that of a 50-cent piece to that of a trash barrel.
- _____ The Argo Merchant's skipper admitted that his vessel was more than 24 miles off course when it went aground and that its gyrocompass was not working at the time of the accident.
- _____ Plankton, sand and ocean debris will slowly collect on the tar balls, increasing their density and causing them to sink.
- _____ The Coast Guard lost \$200,000 worth of equipment that it had installed on the Argo Merchant before the vessel broke in two.
- _____ The Argo Merchant's 7.6 million gallons of number 6 fuel oil are spilled into the sea after the vessel runs aground off Nantucket Island.
- _____ At one stage the Coast Guard burned off a test area of the slick about 25 feet in diameter.
- _____ Two groups of New England fishermen filed suits for a total of \$120 million in damages against the owners of the vessel.
- _____ If environmentalists could find one note of consolation, it was that the sinking of the Argo Merchant seemed certain to focus renewed attention on tanker safety.

Part II

Howard Sanders of the Woods Hole Oceanographic Institution outlines a possible outcome of the oil spill. Place his following statements in the proper sequence:

- _____ Fish heartbeats will increase, their metabolisms will speed up.
- _____ Tiny plants and animals living on the sea bottom will ingest the toxins from the oil.
- _____ Fish growth will be stunted because they will have to expend most of their energy simply staying alive.
- _____ One complete link in the food web could be destroyed, upsetting the ecological balance of the area.
- _____ The fish will reproduce less often, and their offspring may turn out to be weaker than normal.
- _____ Fish will consume the tainted organisms and start to react to the oil-based poisons.

Part III

The diagram which runs across pages 74 and 75 outlines some possible events resulting from the incident described in the article. In the space below, list the events mentioned in their order of occurrence.

TEACHER BACKGROUND - No Greasy Kid's Stuff

"No Greasy Kid's Stuff" gives your students an opportunity to investigate some of the problems relating to oil spill removal. The activities are straight forward and provide an insight into the sticky mess that is an oil spill. Use these activities to emphasize the concepts introduced in the activity "The Worst Oil Spill". Since the likelihood of oil spills is increasing because of the aging of the tanker fleet, and since the technology of the field is changing rapidly, supplementary reports by students can help to keep these materials current.

Old crankcase oil will work well in all of the following investigations. Caution your students to immediately wipe up any spills. The burning of oil poses some problems. Be sure your students use the amount of oil stated and that they wear protective goggles at all times while trying to ignite the oil slick. Refresh your class and yourself with fire extinguisher locations. The risks are minimal but advance planning always pays off. The apparatus used in PART TWO requires a clear cylinder. Glass tubing of large diameters may be obtained from most scientific supply companies. Clear plastic tubing may often be found in aquarium shops.

This activity is best performed in small groups. With the exception of technique V, PART ONE may be completed in one day and PART TWO may be performed the following day. Duplicate the activity pages. One set is recommended per student. If equipment limitations are a problem, have groups begin at different points in the activity. Circulate through the lab as the investigations are performed. Be available to answer questions and spot difficulties. Read through the investigations prior to class and anticipate any problems your class might have. Plan to allot some time for a discussion of the investigations and to provide answers for the questions included in the activity. This is an interesting and timely activity. Have fun.

This activity is adapted from "The Oil Spill Problem" produced by Project COAST, University of Delaware.

KEY

The three ways of removing oil from the surface of the ocean listed might include any of the following:

- a. burning
- b. suction
- c. sinking
- d. skimming
- e. soaking it up (absorption)
- f. detergents
- g. bacteria
- h. others suggested by your students

PART ONE - Removal of Oil from Water

Technique I - Burning

- a. Answers will vary depending upon experimental results. Most will have difficulty in igniting the oil.
- b. Air pollution will occur if the oil is burned.
- c. This question calls for an opinion. The evidence above shows that in most cases burning is not a very effective method for the removal of oil.
- d. One possible situation in which burning might be chosen would be an oil spill close to shore that could not be contained and removed before it caused damage. A second might be a highly volatile and toxic spill. Your students may create other situations. The importance of this question lies in the discussions regarding the trade-offs inherent in the use of any of the methods discussed.

Technique II - Sinking

- a. Answers will vary depending upon observations and the degree of care exercised in performing the investigation. Most will probably say yes, that most or all of the oil was removed from the surface.
- b. The major environmental effect of sinking the oil will be oil pollution of the ocean bottom. Sinking the oil just puts the problem out of sight. ("Out of Sight, out of mind"?)
- c. We should know what the effect of oil will be on bottom dwelling plants and animals before we subject them to oil.

- d. This question asks for an opinion. The evidence presented indicates that sinking is not a good method for cleaning up the pollution caused by oil spills. The burden is just placed on a different group of organisms.
- e. Answers will vary. The submerged oil might reduce sunlight and therefore photosynthesis, it might move in subsurface currents to shelf areas and end up on the bottom anyway, etc. The point should be made that this technique is not a solution, the spill is not gone, we just can't see it doing its damage.
- f. The bottom dwelling (benthic) animals and plants are most likely to be affected by the sunken oil spill.

Technique III - Absorption

- a. Oil is absorbed by the straw.
- b. The oil is not cleaned up. The oil soaked straw must later be cleaned up by booms, suction, fire, etc.
- c. Absorption does contain the oil and is a reasonable procedure for reducing the spread of the spill. The oil soaked straw must be disposed of in some manner and so the problem is not entirely solved by this technique.
- d. Answers will vary. Discuss the problems with each of the techniques (eg. burning, burying, etc.).

e.

$$\frac{100 \text{ pounds}}{\text{bale}} \times \frac{25 \text{ pounds of oil}}{1 \text{ pound of straw}} \times 40,000 \text{ bales} = \frac{1,000,000,000 \text{ pounds of oil}}{\text{of oil}}$$

$$\frac{1,000,000,000 \text{ pounds of oil}}{8 \text{ pounds per gallon}} = 166,666,666 \text{ gallons of oil}$$

The point of these manipulations is to show the vast amounts of oil we're dealing with.

Technique IV - Dispersion

- a. The immediate effect is that the oil breaks up (is emulsified) by the detergent.
- b. Answers depend upon the experimental results. The emulsified oil may separate if the detergent is weak, or it may remain emulsified. The control will remain non-dispersed.
- c. This first question involves an opinion. The detergent does not clean up the pollution, it simply changes its form; from oil to emulsion.

Technique V - Evaporation

- a. Answers depend upon the experimental observations.
- b. Simulation of weather factors, chemical factors, (salinity, pH etc.), and sunlight, would make the model more realistic.

An Overview

- a. While the answers will vary, most students will say the absorption technique had the least harmful effects on the aquatic environment.
- b. The living organism can use the oil for food, and break down the complex oil molecules into simpler molecules that can be used by and/or are not toxic to other animals and plants. The advantage is that the oil is chemically changed into non-harmful products and not just physically moved.
- c. The answers should be obvious but they should also provide an opportunity for a summary discussion of the work to this point.

PART TWO - Oil and The Seashore

Investigation I - Where Did It Go?

- a. Answers depend upon experimental results.
- b. While the answers will vary, most students will say that increasing the number of water additions will change the depth of penetration.
- c. Answers depend upon the experimental results.
- d. Plants and animals beneath the surface do not escape the problems caused by an oil spill on the surface because the oil migrates downward through the sand.
- e. The first few hours the oil is on the beach are critical because the wave action is forcing the oil into the sands and the deeper it does the less likely it is to be removed or removable.
- f. Oily sand can be:
 1. buried
 2. burned
 3. dumped into the ocean

The purpose of this question is to show that scraping simply moves the problem to another location.

Investigation II - Removing Oil from the Beaches

Part A - Penetration

- a. Answers depend upon experimental results
- b. Detergents cause the oil to penetrate deeper into the sand.
- c. No, you would not want to treat the oil with detergents prior to scraping since the detergents force the emulsion deeper into the sand. The scraping would, therefore, be less efficient.
- d. If the oil kills all of the animals in the sand with which it comes in contact, more/~~less~~ animals would be killed if detergents were used to emulsify the oil.

Part B - Sandcastles

- a. Most of your students will find differences in the sand columns. The detergent sand column falls apart while the clean sand holds together.
- b. The detergent sand would be more likely washed away by wave and tidal motion because its particles have less cohesion.
- c. Many experiments are possible. A simple one might involve the use of a wave tank set up and run first with regular sand, then with detergent sand. The results would be compared.
- d. Wave erosion destroys the habitat on which the plants and animals live. If the animals cannot adapt to the changes, they must move or die.
- e. Because of the damage the emulsions cause, detergents do not seem like a good solution for oil spills.

An Overview

- a. Answers will vary. Most of your students will probably think that scraping is the best technique for removing oil from beach sands. Discuss the concept that most of the "solutions" presented are simply transfers - they move the problem to another area.
- b. Answers will vary.
- c. There are many questions we should ask before we use any new product to combat oil spills including:
 1. What is the effect of the product on the animals and plants?
 2. Does the product turn the oil into an even more toxic waste?
 3. What is the chemistry of interactions between the product and the chemicals found in the marine environment?

Your students will have many more ideas. Make the point by way of summary that we need to know as much as we can about a product before we begin widespread use in the environment (whether that environment is aquatic or terrestrial).

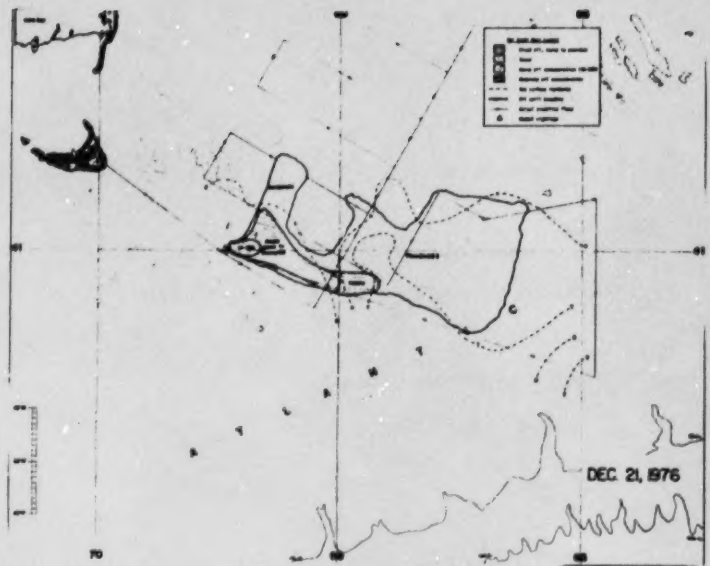
KEY WORDS

absorption
 agitate
 analysis
 apparatus
 aquatic
 bacterium
 column
 control
 density
 detergent

dispersion
droplets
emulsify
emulsion
environment
erosion
experimental
ignite
interpretation
model
oil
penetrate
pillar
pollution
refineries
shoreline
simulate
spill
splint
straw
technique

NO GREASY KID'S STUFF

Coastal waters of the United States are heavily traveled. Major oil refineries are situated along the shorelines, oil tanker traffic is common. In



spite of great efforts made to prevent oil spills, oil spills do occasionally occur. Oil spills have demonstrated the disastrous effects of oil on wildlife and aquatic plant life. Since the oil from spills usually washes ashore, shorebirds and other shore animals and plants are especially likely to suffer. The impact of an oil spill will depend upon many factors: The size of the spill, winds and tides during the spill and the concentrations of organisms in the area affected.

How can we deal with these oil spills? In the following activity you will have a chance to investigate some of the ways oil spills are removed before the oil reaches the shoreline and after the oil reaches the shoreline.

1. List three ways in which oil might be removed from the surface of the ocean to prevent further pollution.
 - a.
 - b.
 - c.

PART ONE - Removal Of Oil From Water

Materials:

large container, non-flammable
oil
Bunsen burner
wood splints
water
goggles
watch with second hand
sand
straw
detergent, concentrated liquid
test tubes (2)
test tube rack
grease pencil or labels

CAUTION: If any oil is spilled, clean it up immediately.
Spilled oil causes unnecessary accidents!
Always wear goggles when working with Bunsen
burners. BE EXTREMELY CAREFUL.

Technique I - Burning

Although technological strides have been made in the area of oil spill removal and cleanup, many rather simple and non-technical methods of cleanup are still extensively used. Perhaps one of the most obvious methods of removal is by burning the oil.

Procedure:

1. Add water to the large container until the water level is within one or two inches of the top.
2. Add about 5 ml of oil to the surface of the water, simulating an oil spill.
3. Ignite a wood splint with the Bunsen burner.

4. Use the burning wood splint to ignite the oil slick.
5. RECORD the length of time the oil burns.

Analysis and Interpretation:

- a. Were you able to ignite the oil?

If so, how long did it burn and was there oil left when the flame went out?

If not, explain what happened when you tried to ignite the oil.

- b. What other type of pollution will probably occur if burning the oil is used as a method of oil spill removal?
- c. In your estimation, is the burning of oil an effective method for the removal of oil? Please explain your answer.
- d. In which situations might you want to use burning as a method of oil spill removal?

Technique II - Sinking

Another very simple method of oil removal is to simply make it sink to the bottom. How might this be done?

Sinking the oil can be brought about by increasing the density of the oil above that of water. This can be done cheaply by simply adding sand, soil, or some other fine, granular or powdered substance to the surface of the oil.

Procedure:

1. Place water in the large container and then place a small quantity of oil on the surface, as was done in Technique I.
2. From your supply of materials, take the sand and sprinkle enough on the surface so that the oil will sink.

Analysis and Interpretation:

- a. Does this method remove all (or most) of the oil from the surface?
- b. When this method is utilized, what other effects will it have on the natural marine environment?
- c. What other observations should be made before this method is used?
- d. In your estimation, is this method a good method of cleaning up the pollution caused by oil spills? Please explain your answer.
- e. Another alternative to complete sinking of the oil is to partially sink it, that is, sink it to a level of 5 to 6 meters below the surface. What good will this do? Will it remedy the problem?
- f. What group of animals and plants is most likely to be affected by the oil spill if the oil is sunk?

Technique III - Absorption

If you have read accounts or seen pictures of the cleanup of oil spills, you are probably familiar with this method of removal.

Procedure:

1. Set up the apparatus as before and pour another layer of oil on the water to simulate a spill. (Don't be concerned with the presence of the submerged oil if you have just finished Technique II.
2. Place a small amount of straw on top of the oil.

Analysis and Interpretation:

- a. What is happening to the oil in relation to the material added?
- b. Does this clean up the oil? How would removal of the oil and straw then be accomplished?
- c. Is this method a fairly reasonable method for cleaning up oil spills? Explain.
- d. How would you dispose of the straw?
- e. Straw has been estimated to absorb from five to forty times its weight in oil. After a serious tanker crash in San Francisco Bay in January, 1971, the Standard Oil Company of California quickly had 40,000 bales of straw available for use by clean-up crews. If we assume that the average 100 pound bale could absorb 25 times its weight in oil, how many pounds of oil were absorbed by the available straw? Please show your work.

If a gallon of the spilled oil weighed 8 pounds, how many gallons of spilled oil were absorbed by the straw?

Technique IV - Dispersion

Detergents have been used to disperse oil spills. Detergents cause the oil to become dispersed throughout the water in the form of tiny droplets. The resulting solution is called an emulsion.

Procedure:

1. Obtain two test tubes and a test tube rack. Label one test tube as the control and the other as the experimental.
2. Fill each test tube with 50 ml of tap water.
3. Add one milliliter of oil to each of the two tubes.
4. To your experimental tube add one ml of detergent.
5. Agitate each tube and place in the test tube rack.
6. Observe each tube immediately after agitation and RECORD your observations of their appearance in the space below.

Control:

Experimental:

7. Allow the tubes to stand overnight and then observe them again. RECORD your observations of their appearance in the space below.

Control:

Experimental:

Analysis and Interpretation:

- a. What was the immediate effect of the detergent on the oil?
- b. Did your observations of the second day differ from those of the first day? In what specific ways did the test tubes change from day one to day two?

- c. Detergents were used to emulsify a massive oil spill near Santa Barbara, California. Researchers noted that "the milky white fluid (caused) a scene of progressive devastation and within a few days virtually nothing remained save for tufts of dead and dying algae." In your estimation, does the dispersion of oil by detergents help in the removal of oil?

Does it clean up the pollution? Please explain your answer.

Technique V - Evaporation

Some oil spills are never contained, treated, or cleaned up. What happens to the oil from these spills?

Procedure:

1. Obtain a container of water and spread a small quantity of oil over the surface. Record your observations in the space below.

Oil:

Water:

2. Let the container sit for two weeks or longer.
NOTE: Water may have to be added from time to time to prevent complete drying.
3. RECORD your observations after the two week or longer period:

Oil:

Water:

Analysis and Interpretation:

- a. How does the character of the oil change with time?
- b. This experimental set-up is a model of the real world. To make the set-up a more realistic model of the world what other factors should we add?

An Overview. . . .

- a. Which technique removed the oil spill from the water with the least damage to the aquatic environment? Please explain your choice.
- b. General Electric Corporation has recently developed and patented a bacterium (yes, a living organism was developed and patented) which is said to eat oil. What advantages would this technique have over those mentioned before?
- c. How do you think the old expression "an ounce of prevention is worth a pound of cure" could be applied to oil spills?

PART TWO - Oil And The Seashore

Oil which is spilled onto the oceans and which cannot be contained and removed can eventually become beached. When this happens, widespread oil pollution along the shoreline can result. The amount of beach covered depends upon many factors including the direction and speed of the wind, the tides, and wave action. How does this beached oil affect the plant and animal life of the beach? How can the oil be removed? The following investigations will give you some of the answers to these questions.

Materials:

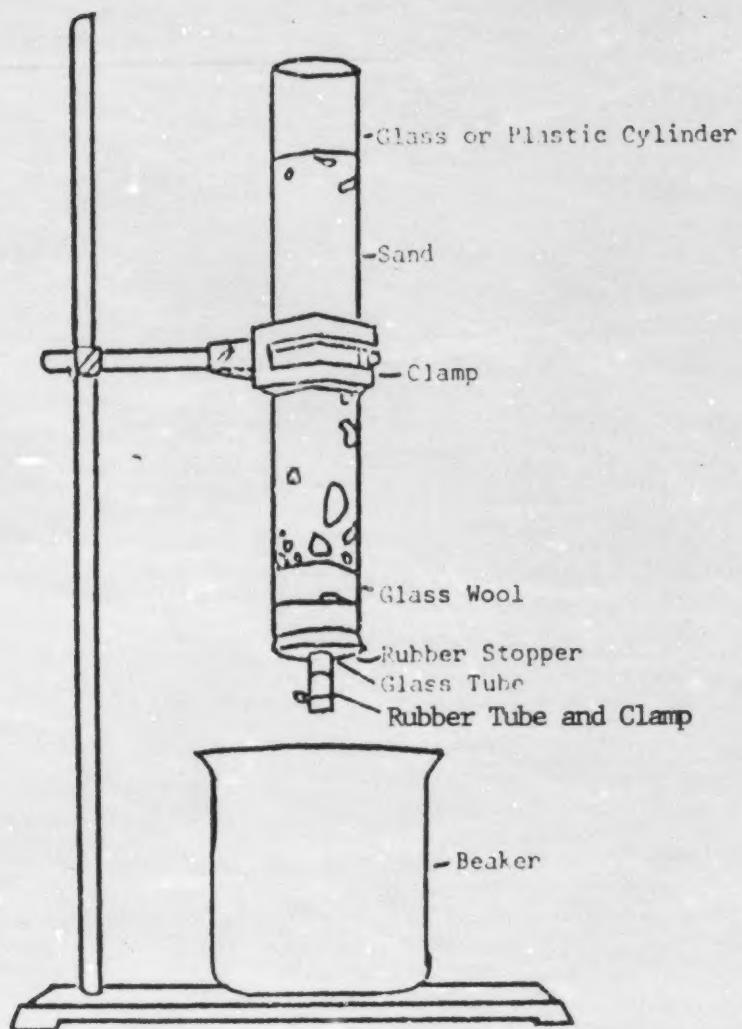
ring stand
glass or plastic cylinder
sand
clamp
glass wool
rubber stopper
glass tube
rubber tube and clamp
beaker
oil
detergent
water

Investigation I - Where did it go?

Procedure:

1. Set up the apparatus shown in the figure below.

Oil Penetration Apparatus



2. Add five ml of oil to the top of the column of sand.
3. With the drain tube clamped, fill the remainder of the column with water. After one minute, release the clamp so that the water will drain off into the beaker.
4. Repeat step 3 twenty times.
5. After you have answered questions a - f below, dismantle and clean your apparatus.

Analysis and Interpretation:

- a. How many millimeters did the oil penetrate into the sand?
- b. Do you think that increasing the number of additions of water would change the depth of penetration?
- c. Test your answer to b, by repeating step 3 five additional times.
- d. Do the plants and animals living beneath the surface of the sand escape the problems caused by oil spilled on the surface? Please explain your answer.
- e. Wave action is like the pouring of the water you did in step 3 above. Why are the first few hours after an oil slick reaches the beach critical in determining how well the beach can be cleaned?
- f. What are two things that can be done with the oily sand?
 - 1.
 - 2.

Investigation II - Removing Oil From The Beaches

When oil spills reach the beaches, attempts are made to clean up the oil as quickly as possible in order to minimize environmental damage. Some of the techniques used are the same as those used to remove oil from the

ocean waters; others are entirely different. Oil absorbing straw is often used on the beach. Mechanical removal of the sand by scraping is also used. Millions of gallons of detergents did not, of course, destroy the oil.

There is some indication that the emulsion droplets may even increase the danger to marine life. What are some of the effects of detergents on the environment?

Part A - Penetration

Procedure:

1. Set up the apparatus as you did in Investigation I.
2. Instead of adding oil, add 7 ml of an oil-detergent emulsion to the top of the sand column. The oil-detergent emulsion is made by mixing 5 ml of oil with 2 ml of detergent in a test tube.
3. With the drain tube clamped, fill the remainder of the column with water. After one minute, release the clamp so that the water will drain off into the beaker.
4. Repeat step 3 twenty times.
5. Save the sand column for Part B.

Analysis and Interpretation:

- a. How many millimeters did the oil emulsion penetrate into the sand?
- b. How did the detergent effect the depth of penetration of the oil?
- c. If you were planning to remove oil on a beach by scraping, would you first want to treat the oil with detergents to emulsify the oil? Please explain your answer.
- d. If the oil kills all of the animals in the sand with which it comes in contact, more/less animals would be killed if detergents were used to emulsify the oil. (Cross out the wrong answer).

Part B - Sandcastles

Procedure:

1. Use the sand column from Part A to make a sand pillar by removing the rubber stopper and gently tapping the column until the sand comes out. Leave the pillar undisturbed while you proceed with step 2.
2. Obtain a quantity of clean sand equal to that from step 1. Replace the rubber stopper in the apparatus and place the sand in the column.
3. Thoroughly wet the sand and remove it as before, forming another sand pillar.

Analysis and Interpretation:

- a. Observe the two pillars. Does there appear to be any differences in how long they stay together?
If so, which pillar stays together longer?
- b. Which of these sands would more likely be washed away (eroded) by natural wave and tidal motion along the shore?
- c. In the space below, design an experiment which would test your answer for question two.

- d. How would wave erosion affect the plants and animals that live on the beach?
- e. Do detergents seem like a good solution for oil spills? Please explain your answer.

An Overview. . . .

- a. Which technique seems best for removing oil from beach sands? Please explain your choice.
- b. Is the best technique for removing oil from sands, also the best technique for removing oil from water?
- c. Before we use any new product to combat oil spills, what are two of the many questions we need to ask (and have answered)?
 - 1.
 - 2.

TEACHER BACKGROUND - Ducking Liability at Sea

The causes of ocean oil spills are manifold. Storms, miscalculation, and ignorance all play a role. So does negligence and, according to the author of "Ducking Liability at Sea", a willful disregard of maintenance and safety. Historically, the life span of a tanker seems to be about a decade. As the first of the supertankers reach their tenth birthday, it behooves governments to closely examine the condition of these vessels. The increase in the size of the ships, has increased the potential for disaster. It is doubtful whether we can afford the luxury of negligence much longer.

"Ducking Liability at Sea" is excerpted from the January/February 1977 issue of Environment Magazine. The article highlights a conflict between economic gain and ecological risk. Money is saved through the Liberian registration of tankers. Unfortunately, the less stringent requirements of the Liberian government increase the likelihood of oil spills. The activity accompanying the article is designed to help your students follow the line of reasoning presented by the author in which he develops his ideas about the dangers of Liberian vessel registration. Since few of your students will know where Liberia is located, it is most helpful to have a world map posted in your room for this activity. Your interested students may wish to check the registry of ships involved in recent oil spills.

Duplicate the activity pages. One set is recommended per student. "Ducking Liability at Sea" is best accomplished by individuals as homework or as an in-class assignment. It is often beneficial to allow your students to meet in small groups and discuss the activity before you discuss the article and questions with the class as a whole. As always, choose the method of instruction that best suits your particular class. In any event, plan to allow time for a discussion of the concepts presented in the article and to provide the answers for the activity.

KEY

A completed activity page follows the "KEY WORDS" section.

KEY WORDS

charter

ducking

liability

Liberia

occurrence

oil tanker

registration

Ducking Liability at Sea

- A. As an introduction to this article, the author mentions five oil tanker accidents that have occurred in the last two weeks of 1976. Refer to page 25 in the article and list the names of the five tankers, where they ran into trouble, where they were registered and what happened.

	<u>Name</u>	<u>Location</u>	<u>Registration</u>	<u>Occurrence</u>
1.	<u>Argo Merchant</u>	<u>27 miles S.E. Nantucket</u>	<u>Liberian</u>	<u>ran aground & broke in half spilling 7.6 million gallons of oil</u>
2.	<u>Sansinena</u>	<u>L.A. harbor</u>	<u>Liberian</u>	<u>exploded & sank</u>
3.	<u>Oswego Peace</u>	<u>Thames river, Connecticut</u>	<u>Liberian</u>	<u>ran aground, released 2000 gallons oil</u>
4.	<u>Olympic Games</u>	<u>Marcus Hook, Phila., P.A. (Delaware River)</u>	<u>Liberian</u>	<u>ran aground, released 134,000 gal. crude oil</u>
5.	<u>Daphne</u>	<u>Puerto Rico</u>	<u>Liberian</u>	<u>ran aground, no oil spilled</u>

- B. If Liberia has no natural harbor, why are so many vessels registered (licensed) in Liberia? Give two reasons.

Liberian registration:

1. *frees a ship from requirements of U. S. law.*

2. *allows owners to disregard U. S. maritime union wage scales.*

3. *freed from U.S. safety and reliability regulations.*

- C. The author notes that "A voluntary tanker-owner agreement signed in 1972 provides that the shippers will pay up to \$100 per ton of oil spilled to cover clean-up costs. In the case of the Argo Merchant, this would not cover even the cost of the clean-up equipment lost in the storm". Refer to the first part of the article and:

1. Find the number of gallons of oil spilled: ^{7.6}million gallons

2. Find the cost of clean-up equipment lost: ^{2 million}dollars

3. Calculate the liability of the tanker owners if a gallon of #6 fuel oil weighs 20 pounds (recall that there are 2000 lbs./ton and that liability per ton is \$100). Show your work, please.

$$\frac{2000 \text{ lbs.}}{\text{ton}} \times \frac{1 \text{ gal.}}{20 \text{ lbs.}} = 100 \text{ gal./ton} \quad \left| \quad \frac{100 \text{ gal.}}{\text{ton}} \times \frac{x \text{ tons}}{7600,000 \text{ gal.}} = 76,000 \text{ tons} \times 100/\text{ton} = \$7.6 \text{ million}$$

4. How much of the clean-up cost could be paid from this liability?

All + left over

- D. What actions have U. S. attorneys taken in the cases of the Argo Merchant and the Olympic Games?

Arrest of Captains

Olympic Games - charged with violation of 1899 Refuse A

Argo Merchant - checking to see if grounding was deliberate

- E. How many serious mishaps occurred in or near U. S. coastal waters in the one month period between 12/15/76 and 1/15/77?

11

Is it reasonable to assume that mishaps may have also occurred in the coastal waters of other nations?

yes

SPECIAL REPORT

1001

DUCKING LIABILITY AT SEA

FIVE OIL TANKERS ran into trouble in U.S. waters in the last two weeks of 1976. At least 9 persons were killed, 50 injured, and nearly eight million gallons of oil were spilled. One of the accidents, off Nantucket, was the worst oil spill in U.S. history and threatens the fisheries of the North Atlantic. All five tankers were chartered in Liberia, and even nominal owners were difficult to identify. A ship captain was arrested in at least one incident. The following summary is compiled from press and wire-service accounts.

ON DECEMBER 15, the Argo Merchant, a 640-foot tanker carrying 7.6 million gallons of No. 6 residual fuel oil went aground 27 miles southeast of Nantucket. The heavy residual oil is used primarily for electric power plant fuel and at winter temperatures has a thick chocolate-pudding consistency. The ship was ten miles off course when it went aground, in some of the best-charted waters in the world, at night in good weather. About 100,000 gallons of oil were spilled at first. The Coast Guard brought steam generators to heat the cargo to make it fluid enough to pump onto barges to lighten the Argo Merchant.

On December 17, in an unrelated accident, the Sansinena, an 810-foot tanker that had just delivered almost three million gallons of crude oil to the Union Oil Company at Los Angeles harbor and was preparing to set out to sea again, exploded. The explosion completely destroyed the ship; its crew of nine, all of Italian nationality, were believed killed, and at least 50 persons on shore were injured. The blast, presumably caused by vapor in the partly empty cargo tanks, was felt in downtown Los Angeles 25 miles away.

The Liberian-registered Argo Merchant grounded 27 miles southeast of Nantucket on December 15.

This disaster focused press attention on the Argo Merchant, still aground off Nantucket, where the oil spill threatened the rich North Atlantic fishery of Georges Bank, as well as local shellfishing. Efforts to heat the heavy oil cargo were hampered by worsening weather. On December 21, a winter storm struck, halting all efforts to salvage the ship, which began to break up. By the following day, the ship had broken in half, and essentially all of its 7.6-million-gallon cargo spilled into the ocean. Twenty-foot waves and freezing temperatures thwarted all attempts to contain the spill. Two million dollars worth of the best available clean-up equipment, including one-of-a-kind experimental devices, were destroyed by the storm. The thick oil spread out in a 60-mile slick over Georges Bank.

Three days later, on Christmas Eve, another Liberian-registered tanker, the Oswego Peace, went aground in the Thames River in Connecticut, releasing 2,000 gallons of light fuel oil. And, December 28, a fourth tanker went aground. The Olympic Games, turning to approach the British Petroleum dock at Marcus Hook, below Philadelphia on the Delaware River, was grounded and spilled 134,000 gallons of crude oil from the Middle East.

The fifth accident struck on December 30, when the Daphne, registered in Liberia, went aground on a sand bar south of Puerto Rico. The Daphne carried 14 million gallons of crude oil, but the Coast Guard, operating in calm seas in the warm Caribbean, pumped 1.7 million gallons onto two barges, lightening the Daphne enough to float it again.

The Argo Merchant spill off Nantucket continued to spread unchecked during this time, covering perhaps 2,000 square miles by year's end. In volume, it was the worst tanker

AP Wirephoto



spill in U.S. waters and the tenth largest anywhere in the world. In potential damage, it may yet be the worst on record, as it covers an area in which much of the world's fish and shellfish are harvested. The Delaware River spill contaminated wetlands in New Jersey, Pennsylvania, and Delaware and affected migratory birds and fisheries as well as the wetlands themselves, but by January 2 Secretary of Transportation William Coleman announced that the spilled oil had been cleaned up and the Olympic Games had been refloated and moved to a safer anchorage. The smaller spill in the Thames River was also cleaned up quickly. The five accidents had an immediate and wide impact on the public and on political figures.

ALL FIVE TANKERS were chartered in Liberia, which has the world's largest fleet, although it has no natural harbor and most of



Esso Photo

OCEAN TRAGEDY

The toll in human life, economic loss, and environmental damage from ocean tanker accidents continued to mount as this issue of *Environment* was completed.

As of this writing, there had been eleven serious mishaps in or near U.S. coastal waters since December 15, 1976. A total of eight accidents involved tankers which were registered in Liberia. This type of registration, as the accompanying story reveals, allows shippers to avoid many regulations which affect U.S.-registered ships. The situation emphasizes inadequacy in international efforts to improve safety of ocean transport. The series of tanker accidents, though serious, also highlights another problem: Tanker accidents and oil spills in tanker operations occur so frequently that many are never brought to public attention. The magnitude of several of the latest accidents, however, was so great that the overall problem became more visible than usual.

In chronological order, the recent accidents were:

December 15 — The Liberian-registered *Argo Merchant* ran aground near Nantucket Island and released 7.6 million gallons of heavy fuel oil.

December 17 — An explosion in Los Angeles harbor split apart the 810-foot *Sansinena*, also Liberian-registered, and left 9 persons dead and 50 injured.

December 24 — The Liberian-registered *Oswego Peace* spilled 2,000 gallons of light fuel oil into the Thames River near Groton, Connecticut.

December 27 — Still another Liberian-registered

tanker, the *Olympic Games*, grounded in the Delaware River near Philadelphia and released 134,000 gallons of crude oil which spread to the shores of three states.

December 29 — The *Daphne*, also of Liberian registration, went aground in Guayanilla Bay, Puerto Rico, but oil was not spilled.

December 30 — In the middle of a winter storm the *Grand Zenith*, registered in Panama and carrying 8.2 million gallons of oil, vanished with a crew of 38, leading to a massive air-sea search which, by January 10, had detected no more than two life-jackets marked with the name of the tanker.

January 4 — The large tanker *Universe Leader*, of Liberian registration, grounded in the Delaware River near Salem, New Jersey, but was refloated without incident.

January 5 — About 2,000 gallons of oil spilled from the 134-foot U.S.-registered *Austin* in San Francisco Bay while the ship was unloading its cargo at a Shell Oil Company facility at Martinez, California.

January 7 — After fourteen hours aground, the rising tide refloated the 700-foot Liberian-registered tanker *Barcola* off the Texas coast without oil being spilled.

January 8 — The Liberian-registered tanker *Mary Ann* was disabled off the Virginia coast after an explosion occurred as one of the ship's empty cargo tanks was being cleaned.

January 10 — One crewman was lost as the small U.S.-registered coastal tanker *Chester A. Poling*, without cargo, broke apart in stormy weather in Boston.

J.

its ships never enter its waters. About two-thirds of Liberia's ships are believed to be owned by U.S. and Greek interests, although actual ownership is difficult to establish. The

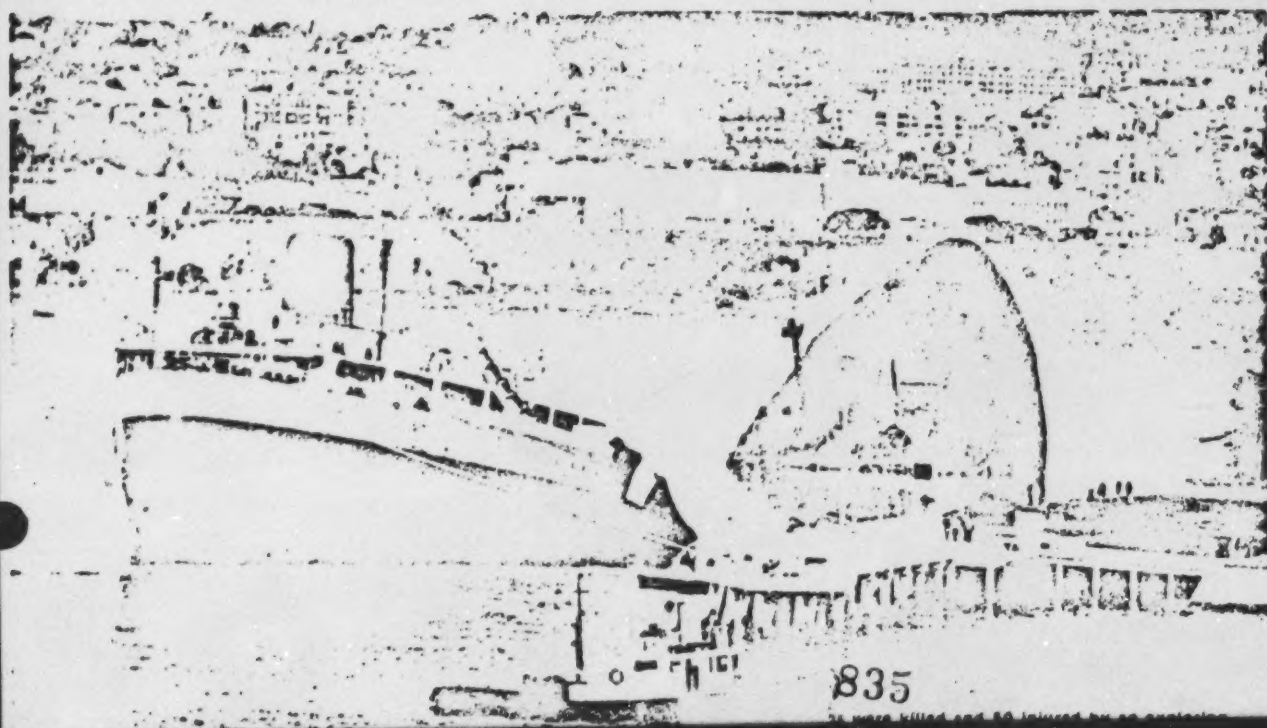
Argo Merchant is reportedly owned by the Amership Shipping Company of Monrovia, Liberia, reported to be a subsidiary of Amership Agency

in New York, which operates seven ships registered in Liberia. Liberia's maritime agencies are also largely in New York City. Amership is not a publicly owned corporation registered in New York; its actual ownership is not yet known. The Olympic Games, the tanker which went aground in the Delaware River, is owned by the Red Bank Shipping Company,

(continued on page 44)

The tanker Argo Merchant was split in two in late December by the force of Atlantic waves. The ship's cargo of oil went into the ocean.

U.S. Coast Guard Photo via AP Wirephoto



AP Wirephoto

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(continued from page 27)

incorporated in Panama and registered in Liberia. Such tankers operate on charter to large oil companies which sometimes control the tanker subsidiaries. In this case, the Olympic Games was under charter to British Petroleum.

LIBERIAN REGISTRY frees a ship from the requirements of U.S. law and allows the shipowner to disregard U.S. maritime union wage scales. Crews of Liberian vessels therefore may be paid as little as one-sixth what U.S. flag vessels must pay; Liberian vessels are also freed from U.S. safety and reliability regulations. A vessel which is too old to meet U.S. standards may be shifted to Liberian registry in a matter of hours. Liberia formerly had no substantial regulations at all, but since 1971, when a disastrous accident occurred in the English Channel, the Liberian government has been trying to impose minimum standards on its renegade fleet. Many of the owners of the ships are corporations in Panama or other states which permit considerable secrecy and impose few or no regulations. Many of the world's 4,500 tankers are operated by such corporations on charter to the seven giant oil companies which dominate world oil shipments. Such corporations generally have few or no assets other than the cargoes they transport. International agreements, implemented in the U.S. by a federal statute in 1951, usually limit a shipowner's liability regarding third persons to the salvage value of the ship and cargo, usually negligible after an accident in any case. A voluntary tanker-owner agreement signed in 1972 provides that the shippers will pay up to \$100 per ton of oil spilled to cover clean-up costs. In the case of the Argo Merchant, this would not cover even the cost of the clean-up equipment lost in the storm. Additional liability may attach to ship owners if it can be shown their ships were not seaworthy when they left port, but it is generally difficult to find anyone to sue or to show the requisite negligence.

In frustration, U.S. attorneys brought actions against ship captains in the Argo Merchant and Olympic Games spills. The captain of the Olympic Games was arrested and charged with violation of the 1899 Refuse Act which prohibits unauthorized dumping in navigable waters. The captain is subject to imprisonment if found guilty. The Argo Merchant captain and other crew members were the principal figures in hearings to determine whether the spill off Nantucket was a result of improper action by the captain or the owners. Press accounts included reports that crew

members charged the grounding was deliberate; the Argo Merchant was an aging tanker at the end of its useful life. The Center for Short-Lived Phenomena reported the ship had been involved in nineteen other accidents, many of them minor. Suits for at least \$60 million were brought in U.S. court on behalf of fishermen in New England.

THE EFFECTS of the year-end accidents have yet to be calculated. The nine deaths and dozens of injuries in Los Angeles harbor were the worst immediate consequences, but long-term damage from the Argo Merchant may ultimately be even worse. The residual fuel oil, after drifting across the shellfisheries off Nantucket and the Georges Bank fishing grounds, appeared to be moving into the Gulf Stream early in January, which might carry it intact across the North Atlantic into the fishing waters off Iceland and perhaps onto the beach of Britain, or it may move back into shallow U.S. coastal waters. Much of the heavy oil mass is suspended beneath the surface and is moving with currents rather than winds. Early reports indicated that little of the oil had settled to the bottom in shallow areas. Oil on the bottom persists for years and may poison the entire food chain, as well as the shellfish harvested from the bottom, and the reports of divers that there had been little settling were therefore welcomed.

--Sheldon Novick



Ducking Liability at Sea



- A. As an introduction to this article, the author mentions five oil tanker accidents that have occurred in the last two weeks of 1976. Refer to page 25 in the article and list the names of the five tankers, where they ran into trouble, where they were registered and what happened.

	<u>Name</u>	<u>Location</u>	<u>Registration</u>	<u>Occurrence</u>
1.	_____	_____	_____	_____
2.	_____	_____	_____	_____
3.	_____	_____	_____	_____
4.	_____	_____	_____	_____
5.	_____	_____	_____	_____

- B. If Liberia has no natural harbor, why are so many vessels registered (licensed) in Liberia? Give two reasons.

1.

2.

- C. The author notes that "A voluntary tanker-owner agreement signed in 1972 provides that the shippers will pay up to \$100 per ton of oil spilled to cover clean-up costs. In the case of the Argo Merchant, this would not cover even the cost of the clean-up equipment lost in the storm". Refer to the first part of the article and:

- Find the number of gallons of oil spilled: _____gallons
- Find the cost of clean-up equipment lost: _____
- Calculate the liability of the tanker owners if a gallon of # 6 fuel oil weighs 20 pounds (recall that there are 2000 lbs./ton and that liability per ton is \$100). Show your work, please.

4. How much of the clean-up cost could be paid from this liability?
- D. What actions have U. S. attorneys taken in the cases of the Argo Merchant and the Olympic Games?
- E. How many serious mishaps occurred in or near U. S. coastal waters in the one month period between 12/15/76 and 1/15/77?

Is it reasonable to assume that mishaps may have also occurred in the coastal waters of other nations?

TEACHER BACKGROUND - Tanker Spill

Man is an important agent of change of the natural environment. Through mining of natural resources, disposal of wastes, water and air pollution, and overuse of land, man has radically changed the balance of nature. Coastal waters of the United States are heavily traveled. Major oil refineries are situated along our shorelines and oil tanker traffic is common. In spite of great efforts made to prevent oil spills, oil spills do occasionally occur. The spills which have occurred have demonstrated the disastrous effects of oil on wildlife and aquatic plant life. Since the oil from spills usually washes ashore, shorebirds and other shore animals and plants are especially likely to suffer. The impact of an oil spill will depend upon many factors: The size of the spill, winds and tides during the spill, and the concentrations of organisms in the area affected.

"Tanker Spill" gives your students an opportunity to create an "oil spill" and to estimate the impact of the "oil" on the shoreline ecosystem. Popped popcorn serves as the "oil". The advantages of popcorn include the fact that it is easily dispersed by wind and waves and that the remnants of the "spill" are eaten (gladly) by shorebirds.

This activity requires access to moving water. A sea or lake beach or stream is ideal. Sites with strong currents, wind, and/or tidal action will show the most dramatic distribution of the oil spill.

The student pages for "Tanker Spill" consist of question cards carried to the site. The question cards require your students to make certain observations. The observations form the basis for the group discussion which follows the activity. Directions for Pre-Trip Activities, On-Site Activities and Post-Trip Activities are found on the next pages. Anticipate any special requirements your class is likely to have. Duplicate the question cards and distribute one set to each student. This activity works well with

small groups. Also take a few minutes to review the general precautions for field tripping which you will find elsewhere in this volume.

PRE-TRIP ACTIVITIES

1. Introduce the topic of oil spills and the possible affects of oil spills on the environment.
2. Make a "Popcorn Slinger" after OBIS:
 - a. Tie a 25 meter cord firmly to one corner of the open end of a cloth bag or pillow case. Tie a loop at the other end of the rope.
 - b. Place a weight (for example, a tennis ball sized rock) in the bottom of the bag and tie it off in one corner to hold it in place.
3. Practice tossing the empty device.
4. Pop about 20 liters of popcorn and fill the bag. (When the bag is tossed into the water, the weight will cause it to sink.) The bouyant popcorn will then float out causing our "oil spill".

ON-SITE ACTIVITIES

1. Introduce the activity. The students will be responsible for estimating the impact of the oil spill on the landscape, the plant and animal life, and on human activities.
2. Provide a set of question cards to each student or group to aid them in their investigations.
3. Ask students to predict where the "oil" will end up and how long it will take to get there.
4. Toss out the popcorn and let the class begin to track it down. You may wish to have your class record their findings on their question cards.
5. At the end of the allocated time, gather all of the students together to discuss their findings. Discussion can be directed by using the questions from the question cards. You may want to summarize the findings by discussing the following impact questions.
 - a. How quickly did the spill reach the shore?
 - b. What agents dispersed the spill? (wind, tide, etc.)
 - c. How might different wind or water conditions affect the spill?
 - d. How could an oil spill be prevented from spreading?
 - e. Who should be responsible for cleaning up the spill?

POST-TRIP ACTIVITIES

1. Please note that item 5 on the preceding page could be completed in the classroom, however, the field site lends itself well to this type of discussion.
2. If the discussion is to occur in the classroom, make sure that each student obtains a copy of the data from all of the groups. This can be accomplished by having the teams write their results on a ditto master.
3. Provide opportunities for the students who have, by now, gained confidence in their abilities to engage in open ended investigation and relevant problem solving.

Materials:

20. liters of popcorn

OBIS popcorn slinger:

1. 25 meter cord
2. cloth bag or pillow case
3. weight (about size of tennis ball, rock will do)

QUESTION CARDSLandscape

Follow the spill and estimate its impact on the landscape. Use a 25-meter length of twine to measure the area the spill covered.

Estimates: Water _____ sq. meters (length times width)
Land _____ sq. meters (length times width)

Where did most of the popcorn end up? Why? How might the underwater landscape be affected? How did the spill change the general appearance of the landscape?

Plant Life

Follow the spill and estimate its impact on plant life. How many different types of plants were affected? Which plants were hardest hit by the spill? Why? How might an oil spill affect land plants? How would animals that eat aquatic plants be affected?

Animal Life

Follow the spill and estimate the impact of the spill on the animal life. How many different types of animals were covered with oil? Which animals were hardest hit by the spill? Why? Which animals do you think would be capable of escaping from a spill? Which animals might not be able to escape? How might an oil spill affect animals that live under rocks in the water?

Human Activities

Follow the spill and estimate its impact on human activities. How might an oil spill affect fishing and other recreation activities such as swimming, water skiing, surfing, diving, etc? How might boats, docks, breakwaters, and other water structures be affected? How might drinking water or food be affected by an oil spill?

"Tanker Spill" is adapted from "Oil Spill" an activity developed by OBIS (Outdoor Biology Instructional Strategy) from the Lawrence Hall of Science, University of California, Berkeley.

TEACHER BACKGROUND - "Food Resources of the Ocean"

Increasingly people look to the seas for sources of food to support the growing human population. How will this interaction with the sea occur? What will be the effect of fish populations on the sea as a whole? S. J. Holt in his article "The Food Resources of the Ocean" takes a close look at our expectations of the sea and the ways in which we may meet some of our expectations while maintaining the biological processes that give our planet its special character. The article contains a good explanation of the concept of sustained yield harvesting an equally good discussion about the effects of modern non-selective fishing gear on fish populations. The article may present a reading challenge for some of your students. To help your students succeed with this exercise a reading guide is included in which your students are asked to complete main idea sentences. The sentences occur in the same order as they are found in the article. While the article is challenging, it is understandable. The message the article conveys is important for our understanding of the role of the oceans in supporting human populations. Help your students to comprehend the message.

Duplicate the activity pages. One set is recommended per student. The activity best lends itself to completion as a homework assignment or as an in-class assignment. The article is lengthy and you may wish to allow two nights for completion. Watch for signs of frustration on the part of your students and provide encouragement and help to those students who demonstrate a need. Your less able readers will profit from a strategy which has your students meet in small groups to discuss their answers and to come to a consensus before you discuss the article and provide answers to the class as a whole. As you discuss the article emphasize the importance of careful husbandry of the seas. It is important that your students understand that the sea, like the land, is capable of producing

only a finite amount of food.

KEY

A completed guide follows the "KEY WORDS" section.

KEY WORDS

anchovies
apparatus
appropriation
catch
cultivate
extinct
finfish
fish stock
flout
fluctuation
foodstuff
harvest
mariculture
optimum
overexploitation
paraphrase
pelagic
plaice
pollution
population
predictive
quantitative
regulation
require
resources
selective gear
sustained yield

Food Resources of the Ocean

Below you will find a number of incomplete sentences. The sentences paraphrase important ideas mentioned by the author. In each sentence a key word has been omitted. Read the article and fill in the missing key words. The sentences appear in the same order below as in the article. Transfer the letters in the numbered spaces to their corresponding space in the mystery sentence below. The mystery sentence will make sense if you have correctly answered all of the key words.

W 1 I 2 L 3 L 4 I 5 H 6 F 7 F 8 O 9 O 10 D 11 R 12 F 13 S 14 O 15 U 16 R 17 C 18 E 19 S
 O 20 F 21 I 22 H 23 F 24 O 25 C 26 E 27 A 28 N 29 F 30 F 31 F 32 D 33 A 34
 G 35 R 36 O 37 N 38 I 39 N 40 G 41 P 42 O 43 P 44 U 45 I 46 A 47 I 48 I 49 O 50 N 51 ? 52 R 53 E 54 A 55 D 56
 O 57 N 58 !

- The two most important uses of the ocean are 12 S 13 H 14 I 15 P 16 P 17 I 18 N 19 G and fishing.
- Of the 55 million metric ton ocean harvest, more than 90 percent is 22 F 23 I 24 N 25 F 26 I 27 S 28 H.
- Fish is one of the few major 32 F 33 O 34 O 35 D 36 S 37 I 38 U 39 F 40 F 41 S that continues to exceed the growth rate of the human population.
- The 46 P 47 A 48 C 49 I 50 F 51 I 52 C 53 O 54 C 55 E 56 A 57 N provides the biggest share of the fish caught. (2 words)
- With the greatest one-species fishery (10 million tons of anchovies per year) 58 P 59 E 60 R 61 U has become the country with the largest fish catch.
- When the stock of a fish species neither decreases nor increases when fished, we have a 67 S 68 U 69 S 70 I 71 A 72 I 73 N 74 F 75 D yield.

7. $\frac{F}{7} \frac{L}{3} \frac{U}{34} \frac{C}{2} \frac{T}{34} \frac{U}{42} \frac{A}{42} \frac{T}{43} \frac{I}{43} \frac{O}{43} \frac{N}{43}$, which causes the fish stock to vary in abundance from year to year, is a significant characteristic of living marine resources.
8. The largest catch of an individual fish species involves the Peruvian $\frac{A}{47} \frac{N}{24} \frac{C}{21} \frac{H}{8} \frac{O}{8} \frac{V}{41} \frac{E}{34} \frac{T}{34} \frac{A}{34}$.
9. An unregulated fishery tends to expand beyond its $\frac{O}{7} \frac{P}{36} \frac{T}{7} \frac{I}{2} \frac{M}{2} \frac{U}{2} \frac{M}{2}$ point usually due to over-exploitation.
10. We still have very incomplete knowledge, in $\frac{O}{30} \frac{U}{30} \frac{A}{30} \frac{N}{41} \frac{T}{2} \frac{I}{2} \frac{T}{2} \frac{A}{2} \frac{T}{2} \frac{I}{2} \frac{V}{2} \frac{E}{2}$ terms, of the living resources of the ocean.
11. The best prediction seems to be that the potential catch is about $\frac{T}{15} \frac{H}{6} \frac{R}{6} \frac{E}{6} \frac{E}{6}$ times the present global catch.
12. To double the catch we have to more than double the amount of fishing, because the stocks $\frac{D}{10} \frac{E}{24} \frac{C}{24} \frac{L}{2} \frac{I}{2} \frac{N}{2} \frac{E}{2}$ in abundance as they are exploited.
13. We probably have something to learn from studying, before they become extinct, some kinds of traditional " $\frac{P}{36} \frac{R}{32} \frac{I}{2} \frac{M}{20} \frac{I}{20} \frac{T}{20} \frac{I}{20} \frac{V}{20} \frac{E}{20}$ " fishing gear that take advantage of subtleties of fish behavior observed over many centuries.
14. The exploitation of deep $\frac{P}{25} \frac{E}{37} \frac{L}{37} \frac{A}{35} \frac{G}{2} \frac{I}{2} \frac{C}{2}$ resources awaits the development of suitable fishing apparatus.

15. As fishing is intensified throughout the world, it becomes at the same time less $\frac{S}{12} \frac{E}{25} \frac{L}{20} \frac{E}{20} \frac{C}{20} \frac{T}{20} \frac{I}{20} \frac{V}{20} \frac{E}{20}$.
16. Overfishing in the North Atlantic and adjacent waters began some 80 years ago in the North Sea, when further increases in fishing the $\frac{P}{26} \frac{L}{30} \frac{A}{2} \frac{I}{2} \frac{C}{2} \frac{E}{2}$ stock no longer produced an increase in catch of that fish.
17. The author sees two possible forms of ocean regulation, a form of international "ownership" or the $\frac{A}{47} \frac{P}{36} \frac{P}{36} \frac{B}{33} \frac{O}{43} \frac{P}{43} \frac{R}{2} \frac{I}{47} \frac{A}{47} \frac{I}{47} \frac{I}{49} \frac{O}{37} \frac{N}{37}$ of wide ocean areas by coastal nations.
18. The tighter the squeeze on the natural resources, the greater the suspicion of fishermen that "the others" are not abiding by the regulations, and the greater the incentive to $\frac{F}{18} \frac{L}{13} \frac{O}{13} \frac{U}{13} \frac{T}{13}$ the regulations oneself.
19. Mariculture in the open sea awaits a regime of $\frac{L}{37} \frac{A}{26} \frac{W}{1}$ there, and effective management as well as more research.
20. The greatest threat to mariculture is perhaps the growing $\frac{P}{36} \frac{O}{18} \frac{L}{18} \frac{L}{18} \frac{U}{38} \frac{T}{2} \frac{I}{22} \frac{O}{44} \frac{N}{44}$ of the sea.
21. By the turn of the century the sea will be less a $\frac{W}{1} \frac{I}{2} \frac{L}{48} \frac{D}{48} \frac{E}{48} \frac{R}{48} \frac{N}{22} \frac{E}{22} \frac{S}{22} \frac{S}{22}$ and more cultivated.

THE FOOD RESOURCES OF THE OCEAN

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Food Resources of the Ocean

Below you will find a number of incomplete sentences. The sentences paraphrase important ideas mentioned by the author. In each sentence a key word has been omitted. Read the article and fill in the missing key words. The sentences appear in the same order below as in the article. Transfer the letters in the numbered spaces to their corresponding space in the mystery sentence below. The mystery sentence will make sense if you have correctly answered all of the key words.

W
 1 2 3 3 4 5 6 7 8 9 10 11 6 12 13 14 15 16 6 17
 18 19 20 21 22 23 24 25 26 27 28 6 6 29 30
 31 32 33 W 1 2 34 35 36 37 38 39 40 41 2 43 44 ? 45 6 47 48
 49 50 !

- The two most important uses of the ocean are _____ and fishing.
 12 — 2 — 16 2 — 31
- Of the 55 million metric ton ocean harvest, more than 90 percent is _____.
 28 — 27 — 2 — 5
- Fish is one of the few major _____ that continues to exceed the growth rate of the human population.
 8 29 — 4 — — —
- The _____ provides the biggest share of the fish caught. (2 words)
 16 — 7 — 16 23 — 6 — 44
- With the greatest one-species fishery (10 million tons of anchovies per year), _____ has become the country with the largest fish catch.
 11 14
- When the stock of a fish species neither decreases nor increases when fished, we have a _____ yield.
 17 — — — 40 2 50 — 29

7. $\frac{7}{3} \frac{34}{34} \frac{40}{40} \frac{43}{43}$, which causes the fish stock to vary in abundance from year to year, is a significant characteristic of living marine resources.
8. The largest catch of an individual fish species involves the Peruvian $\frac{47}{24} \frac{21}{8} \frac{41}{30}$.
9. An unregulated fishery tends to expand beyond its $\frac{7}{36} \frac{4}{2}$ point usually due to over-exploitation.
10. We still have very incomplete knowledge, in $\frac{30}{41} \frac{2}{2}$ terms, of the living resources of the ocean.
11. The best prediction seems to be that the potential catch is about $\frac{15}{6} \frac{6}{6}$ times the present global catch.
12. To double the catch we have to more than double the amount of fishing, because the stocks $\frac{10}{24} \frac{2}{2}$ in abundance as they are exploited.
13. We probably have something to learn from studying, before they become extinct, some kinds of traditional " $\frac{36}{32} \frac{2}{20}$ " fishing gear that take advantage of subtleties of fish behavior observed over many centuries.
14. The exploitation of deep $\frac{25}{37} \frac{35}{2}$ resources awaits the development of suitable fishing apparatus.

15. As fishing is intensified throughout the world, it becomes at the same time less 12 — — 25 — 20 — — .
16. Overfishing in the North Atlantic and adjacent waters began some 80 years ago in the North Sea, when further increases in fishing the 36 39 — 2 — — stock no longer produced an increase in catch of that fish.
17. The author sees two possible forms of ocean regulation, a form of international "ownership" or the 47 36 — — 33 — 43 2 47 — — 49 34 of wide ocean areas by coastal nations.
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19. Mariculture in the open sea awaits a regime of 39 26 1 there, and effective management as well as more research.
20. The greatest threat to mariculture is perhaps the growing 36 18 — — 38 — 2 37 44 of the sea.
21. By the turn of the century the sea will be less a 1 2 — 48 — 45 — 22 — — and more cultivated.

SEND-IN PAGE

Well, you've made it. Thank you for teaching about the marine environment. We worked hard to put this unit together and we would really like to hear from you. If you have any reactions (positive or negative) that could help us, please let us know. Did you make any changes in the activities which made them more useful to you? If so, could you let us know about them? If you have some marine activities that you have tried successfully with your students, we would like to know about them also. Perhaps we can help you share your working ideas with other teachers concerned with the marine environment. Again, thanks and keep up the good work.